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THE WAY OF THE WIND.*

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THEORY, MATHEMATICAL.

THE way of the wind is devious and strange. It "bloweth where it listeth." Its laws are neither the laws of the laboratory nor the common sense of the shop. It continually changes its course, except as strenuously prevented; veers with increase of height; and in whatever direction pushed contrarily takes another. All this complication, and a lot more, comes of the facts that the earth is a rotating sphere, and the air a viscous fluid. Also there are many other factors that disturb the way of every wind that blows; commonly, however, these are of minor importance, and for that reason here will be given only the briefest consideration, however tempting the problems they present.

Cause of Wind.—The underlying cause of every natural movement of the atmosphere, every large-scale example of air in motion, is difference of temperature. The warmer column of air, because of its expansion, overflows any adjacent colder one, thereby so altering their surface pressures as to establish a complete circulation between them—a gravity phenomenon induced and maintained by difference of temperature.

* Address delivered Wednesday, September 17, 1924, on the occasion of the celebration of the centenary of the founding of The Franklin Institute.

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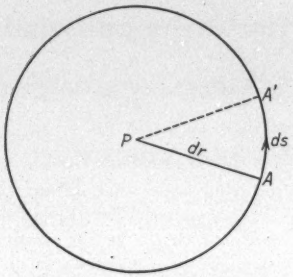
Deflection Due to the Earth's Rotation.—It will be convenient to consider first, in a simple way, the change of wind direction, or tendency to such change, caused by the rotation of the earth. To this end let a frictionless mass m cross a pole P (Fig. 1) of the earth with the velocity v, and under no restraint except that of gravity. It therefore will remain in a fixed plane in space containing the axis of the earth, whatever its course over the surface. Let A be the point actually reached in the very short time dt after passing the pole, and A' the place it would have

FIG. 1.



Deflection due to the rotation of the earth.

reached in the same time, obviously equally distant from the pole, if the earth had not been rotating. Call this distance dr, and the arc AA' ds. Then

$$dr = vdt,$$

and, since ds increases linearly with time,

$$ds = \frac{1}{2} a (dt)^2,$$

in which a is acceleration. But

$$ds = dr\omega dt = v\omega (dt)^2$$

in which ω is the angular velocity of rotation of the earth. Hence

$$a = 2\omega v.$$

Clearly, then, to compel this mass m to move along a given meridian, a force would have to be exerted on it, always at right angles to its line of motion, of the value

$$f = ma = 2mv\omega.$$

At other parts of the world the rate of rotation is $\omega \sin \varphi$, in which φ is the latitude. Hence, in general,

$$f = 2mv\omega \sin \varphi. \qquad (1)$$

That is, the deflective force of a moving portion of air, or the force it would exert if constrained to move in the same geographic direction, is:

(*a*) Directly proportional to its mass;

(*b*) Directly proportional to its horizontal velocity;

(*c*) Directly proportional to the angular velocity of the earth's rotation;

(*d*) Directly proportional to the sine of the latitude of its location;

(*e*) Exactly the same whatever its horizontal direction;

(*f*) Always at right angles to its instantaneous direction, hence without effect on its velocity;

(*g*) Opposite to the direction of the earth's rotation, hence to the right, or clockwise, in the northern hemisphere; to the left, or counterclockwise, in the southern.

Total Horizontal Deflecting Force.—If the course of the wind is not along a great circle, and generally it has a smaller curvature, the total force necessary and sufficient to hold it on its path, in case there is no friction, is, per mass m,

$$F = 2m\omega v \sin \varphi \pm mv^2/r, \qquad (2)$$

in which

$$r = R \tan \alpha,$$

R being the radius of the earth and α the angular radius of the path of the wind as seen from the centre of the earth.

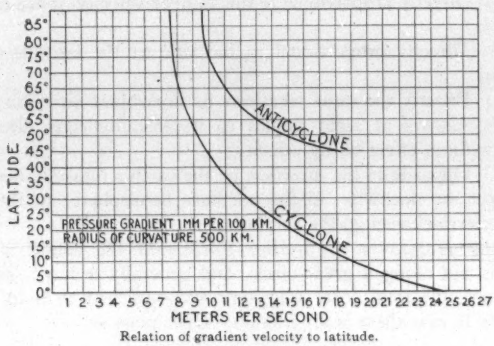
The positive sign applies, that is, the geostrophic (due to rotation of the earth) and the cyclostrophic (due to curvature of path, centrifugal) forces are additive, when the wind, in the northern hemisphere, is counterclockwise, and the negative sign when it is clockwise. In the southern hemisphere the reverse condition holds—there the positive sign applies to clockwise winds, and the negative to the counterclockwise. In other words, the geostrophic and the cyclostrophic forces are additive, the world over, for cyclonic winds, and subtractive for the anticyclonic.

Gradient Velocity.—That velocity of the wind at which the deflective force, due to the rotation of the earth, and the centrifugal force jointly balance the horizontal pressure gradient (the derivative of the barometric pressure with reference to dis-

tance in the direction of the most rapid horizontal change of pressure) is called the gradient velocity. It does not occur near the surface of the earth, owing to the drag due to friction and turbulence, but does occur, approximately, at every height as great as half a kilometre or more.

By writing the pressure gradient in the form dp/dn in which p is the atmospheric pressure, and n the distance normal horizon-

FIG. 2.



Relation of gradient velocity to latitude.

tally to the current isobar, and representing the density of the air by ρ, we have

$$\frac{1}{\rho}\frac{dp}{dn} = 2v\omega \sin\varphi \pm \frac{v^2}{r}. \tag{3}$$

The positive sign in this equation applies, as stated above, to cyclonic winds, or winds circulating about a low-pressure centre, and the negative to anticyclonic winds—those about a high-pressure centre. Hence, under like conditions, anticyclonic winds are stronger than cyclonic.

The gradient velocity, therefore, is, for cyclones

$$v = \sqrt{\frac{r}{\rho}\frac{dp}{dn} + (r\omega \sin\varphi)^2} - r\omega \sin\varphi, \tag{4}$$

and for anticyclones

$$v = r\omega \sin\varphi - \sqrt{(r\omega \sin\varphi)^2 - \frac{r}{\rho}\frac{dp}{dn}}. \tag{5}$$

Clearly, in the case of the cyclonic winds there is no theoreti-

cal maximum; while for the anticyclonic, as pointed out by Gold,[1] there is, namely,

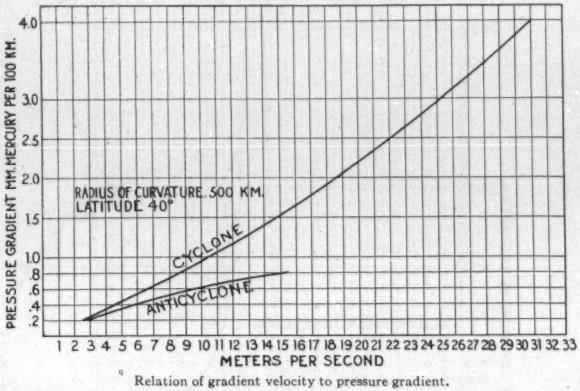
$$V = r\omega \sin \varphi, \tag{6}$$

corresponding to the pressure gradient

$$\frac{dp}{dn} = \rho r (\omega \sin \varphi)^2. \tag{7}$$

On substituting this value of the gradient in equation (3), it

FIG. 3.



Relation of gradient velocity to pressure gradient.

appears that for straight isobars ($r = \infty$), hence straightaway winds,

$$V = \frac{1}{2} r\omega \sin \varphi. \tag{8}$$

That is, gradient for gradient, the maximum possible velocity of wind in an anticyclone is exactly twice that of a straightaway wind.

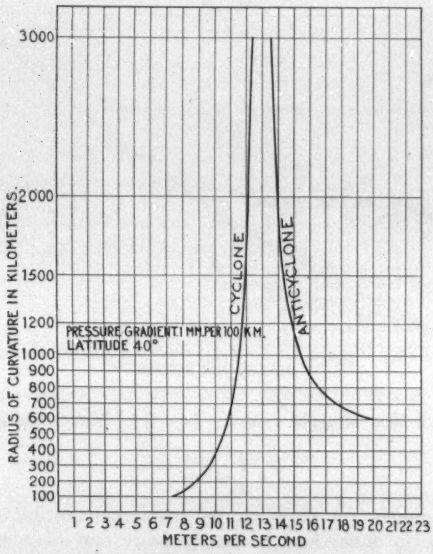
Some of these relations of gradient wind-velocity to the place and conditions under which it is produced are well shown graphically; thus, Fig. 2 gives its relation to latitude; Fig. 3 its relation to pressure gradient; and Fig. 4 its relation to radius of curvature.

Automatic Adjustment of the Wind to Gradient Direction and Velocity.—In considering the frictionless movement of the air, such as approximately obtains at the half-kilometre level, and upwards, it is convenient to adopt the fiction that the earth is at

[1] M. O., No. 190, London, 1908.

rest, and the wind under the control of three separate forces: (*a*) The deflective or geostrophic force, owing to the earth's rotation; (*b*) the horizontal component of the centrifugal or cyclostrophic force, owing to the curvature of the wind path; and (*c*) the horizontal or gradient pressure, due to gravity. The first two, the geostrophic and the cyclostrophic forces, are normal to the

FIG. 4.



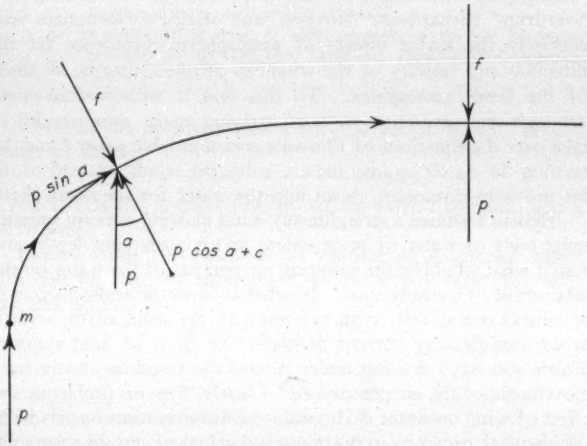
Relation of gradient velocity to radius of curvature.

path, hence in no wise affect the strength of the wind, which, therefore, depends wholly upon the horizontal pressure gradient.

Let, then, m, Fig. 5, be an isolated mass of frictionless air, in the northern hemisphere, and initially at rest. Now, let it be pushed by a force p of constant magnitude and constant geographic direction, north, say. Immediately the mass moves, the geostrophic force f, or $mv\omega \sin \varphi$, becomes operative, curving the path east of north, and introducing the cyclostrophic force c, or mv^2/r. Clearly, so long as the angle between the path of the

air and the direction of the force p is less than 90°, there will be a component of the latter in the line of motion and the speed of the wind will be increased. If for any reason this angle should exceed 90°, there would be a component of this force backwards which would decrease the speed, and thereby also the geostrophic force. That is, in the northern hemisphere, air pushed north soon blows east, pushed east blows south, pushed south blows

FIG. 5.



Deflection and path of winds in frictionless flow under a force of constant magnitude and constant geographic direction.

west—always at right angles to the line of thrust, however one may box the compass; while in the southern under like circumstances it blows exactly contrariwise—west instead of east, north instead of south, and so on around the circle in a manner quite at variance with common sense and everyday experience.

It is this blowing of the winds at right angles to the pressure gradient, hence around and not towards centres of pressure, both low and high, that makes possible the long life of the cyclone and of the anticyclone. If the free air of all outdoors obeyed the same laws it does, or seems to, in the microcosm of the laboratory, practically all surface winds would be essentially polar (blowing directly from the nearest pole), and the climates of the earth,

at least in many places, disastrously different from what they now are.

Surface Drag and Turbulence.—All the above discussion applies, as stated, only to frictionless air, hence, approximately, to the atmosphere at and beyond half a kilometre above the surface, and not to that of lower levels where surface friction and turbulence occur. However, it is possible now, from the classical papers of Ekman,[2] Akerblom,[3] Taylor,[4] Hesselberg and Sverdrup,[5] Richardson,[6] Jeffreys,[7] and others, to formulate very concisely the major effects of atmospheric turbulence on the direction and velocity of the winds so affected, that is, all those of the lower atmosphere. To this end it will be convenient (though there are other ways of arriving at the same result) to take over the equations of Ekman's oceanographic paper[8] and, by turning the z-axis up into the air, solve for winds, instead of, as his problems demanded, down into the water for the ocean drift.

Ekman assumed a straightaway wind blowing over an initially quiet body of water of great extent and considerable depth, and found what would be the resulting movements of the water on the attainment of a steady state. In what follows the atmosphere will be considered at rest, with reference to the solid earth, with a broad straightaway current of water (or drift of land surface, prairie sod, say) flowing under it, and the resulting steady-state movements of the air determined. Clearly, the two problems, the effect of wind on water drift, and of a water current on air drift, are identical, except as to the numerical values of certain constants. Hence the equations used by Ekman in the solution of the ocean drift problem may be taken over without change for the solution of the similar wind problem. Clearly, too, the final results will be directly applicable to all steady winds, whether over land or over water, for a wind is only motion as between earth and air.

[2] "On the Influence of the Earth's Rotation on Ocean Currents," *Arkiv för Mat. Astr. och Fysik*, 1905.

[3] "Sur les courants les plus bas de l'atmosphère," *Nova Acta Reg. Soc. Upsaliensis*, 1908.

[4] "Eddy Motion in the Atmosphere," *Phil. Trans.*, A215, 1–26, 1914.

[5] *Geophys. Inst. Leipzig*, Ser. 2, Heft 10, 1915; *Beit. z. Phys. fr. Atmos.*, 7, 156–166, 1917.

[6] *Proc. Roy. Soc.*, A96, 9–18, 1919; A97, 354–373, 1920.

[7] *Proc. Roy. Soc.*, A96, 233–249, 1919.

[8] *Loc. cit.*

Let the origin of the rectangular coördinates x, y, and z be on the surface (land or water) of the earth, z being vertical and positive upwards, and the positive direction of y 90° counter-clockwise from the positive direction of x, as seen from above. Let

u, v = the velocity components of the air drift in the directions of x, y;
X, Y = the x, y components of extraneous forces per unit mass of the air, assumed constant with height;
ρ = the density of the air, regarded constant, which it is, roughly, through at least the first half kilometre;
μ = the coefficient of drag, or eddy viscosity, of the air, considered constant through the eddy layer—an allowable first approximation;
t = the time.

Then, in the northern hemisphere (or southern, with proper change of signs),

$$X = 2v\omega \sin \varphi; \qquad Y = -2u\omega \sin \varphi;$$

in which ω is the angular velocity of the earth's rotation, and φ the latitude.

Hence, from the equations of motion of a viscous fluid,[9] remembering that, by assumption, u and v can vary only with time and height,

$$\frac{\partial u}{\partial t} = 2v\omega \sin \varphi + \frac{\mu}{\rho} \frac{\partial^2 u}{\partial z^2},$$
$$\frac{\partial v}{\partial t} = -2u\omega \sin \varphi + \frac{\mu}{\rho} \frac{\partial^2 v}{\partial z^2}.$$

For steady motion, and on writing

$$\rho\omega \sin \varphi / \mu = a^2,$$

these equations reduce to

$$\frac{\partial^2 u}{\partial z^2} + 2a^2 v = 0,$$
$$\frac{\partial^2 v}{\partial z^2} - 2a^2 u = 0, \qquad (9)$$

the general solution of which is

$$u = C_1 e^{az} \cos (az + k_1) + C_2 e^{-az} \cos (az + k_2),$$
$$v = C_1 e^{az} \sin (az + k_1) - C_2 e^{-az} \sin (az + k_2),$$

in which C_1, C_2, k_1, k_2, are arbitrary constants.

Clearly, the drag is zero, hence u and v are zero, when z is infinite. Indeed the drag is approximately zero at half a kilometre, or thereabouts, above the surface, since at that level the speed and

[9] See, for instance, LAMB, "Hydrodynamics," fifth ed., pp. 546–547.

direction of the wind are practically what they would be under the existing pressure gradient if the atmosphere were a perfect fluid.

If, then, u and v are each to be zero when z is infinite, obviously C_1 is zero. Hence

$$\begin{aligned} u &= C_2 e^{-az} \cos(az + k_2) \\ v &= -C_2 e^{-az} \sin(az + k_2) \end{aligned} \tag{10}$$

and

$$\begin{aligned} \frac{du}{dz} &= -aC_2 e^{-az} \{\sin(az + k_2) + \cos(az + k_2)\} \\ &= -a\sqrt{2}C_2 e^{-az} \sin(az + k_2 + 45^0) \\ \frac{dv}{dz} &= aC_2 e^{-az} \{\sin(az + k_2) - \cos(az + k_2)\} \\ &= -a\sqrt{2}C_2 e^{-az} \cos(az + k_2 + 45^0) \end{aligned}$$

If the tangential drag of the surface on the air is T, and in the positive direction of y, then

$$\mu \left(\frac{du}{dz}\right)_{z=0} = 0, \qquad -\mu \left(\frac{dv}{dz}\right)_{z=0} = T. \tag{11}$$

Hence

$$\begin{aligned} k_2 &= -45^0 \\ C_2 &= \sqrt{u^2 + v^2} = V_0 \end{aligned}$$

$$\begin{aligned} u &= V_0 e^{-az} \cos(45^0 - az) \\ v &= V_0 e^{-az} \sin(45^0 - az) \end{aligned} \tag{12}$$

$$V_0 = T/\mu a\sqrt{2} = T/\sqrt{2\mu\rho\omega \sin\varphi}. \tag{13}$$

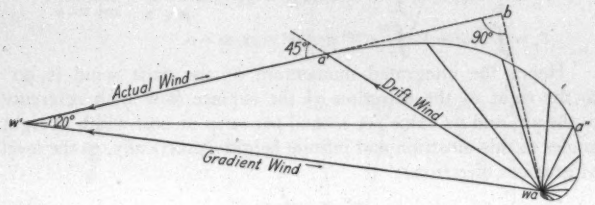
Since the tangential drag T of the water (or land) on the air is, by assumption, in the positive direction of y, and, of necessity in the direction of the surface movement with reference to the air, it follows from the equations (12) that, in the northern hemisphere, the drift of the air just above the surface ($z = 0$, components u and v of V_0 equal to each other and positive) is 45° to the right of the direction of the surface current relative to the air. In the southern hemisphere the air drift is 45° to the left of the surface current.

Since the value of a is independent of height, z may be counted from any level, provided T is the drag between the superjacent layers of air at that level, and V_0 the corresponding drift velocity. Hence the projection of the drift envelop onto the ground or water surface is an equiangular, 45° or 135°, spiral about the initial contact point of air and surface.

The relations between the air and surface movements are

shown in Fig. 6 (as over water—over land the angle i is around 30°), in which wa, is the contact position of certain adjacent air and surface particles at a given instant, w' the position of the same surface particle at a given subsequent instant, and a' the position, at the same subsequent instant, of the initial air particle. That is, with reference to the earth beneath, ww' is the direction and speed of the surface, and aa' the consequent direction and speed of the air. Hence $a'w'$, inclined 135° to aa', is the direction and speed of the surface with reference to the air, and, of course,

FIG. 6.



The equiangular wind spiral.

$w'a'$ that of the air with reference to the surface. That is, $w'a'$ is the direction and speed of the surface wind.

It should be noted in this connection that since the angle $w'a'w$ between the directions of the surface wind and the "drift wind" has to be 135°, therefore the speed of the surface wind decreases as its inclination to the isobar increases, becoming zero as this angle reaches its limit, 45°.

From equations (12) it is further obvious that the angle between the directions of the driving surface and the resulting air drift increases uniformly with height, two right angles for each π/a gain therein; and also that the velocity of the drift continuously decreases, as the height grows greater, falling to the $\epsilon^{-\pi}$th, or, approximately, the 1/23 part of its initial value for any π/a ascent.

The speeds and directions of the drift currents at the heights 0, $\pi/10a$, $2\pi/10a$, and so on, of which wa'' is an example, are shown in Fig. 6, projected onto the surface, or xy plane. The direction and velocity of this actual wind at the height corresponding to the drift wa'' are given by $w'a''$, and similarly for other heights.

If we assume the turbulence drag to be substantially zero at

that level at which the wind, as we go up, attains the direction of the isobars, that is, where the angle of inclination i, Fig. 6, becomes zero, and call this height H, then, clearly

$$H = 3\pi/4a = \frac{3}{4}\pi\sqrt{\frac{\mu}{\rho\omega\sin\varphi}}. \tag{14}$$

To find the total momentum given to the air per unit of time by the drag T, let F_x be the total flow in the positive direction of x across a strip of infinite height and unit width at right angles to x, and F_y the similar total flow in the direction of y. Then

$$F_x = \int_0^\infty u\,dz = V_0\int_0^\infty e^{-az}\cos(45^\circ - az)\,dz = \frac{V_0}{a\sqrt{2}} = \frac{T}{2\rho\omega\sin\varphi},$$

$$F_y = \int_0^\infty v\,dz = V_0\int_0^\infty e^{-az}\sin(45^\circ - az)\,dz = 0.$$

Hence the integrated momentum of the drift wind is 90° to the right of the direction of the surface flow with reference to the air, and its value per second per strip of unit width at right angles to this direction and infinite height (practically, to the level of gradient direction),

$$\rho F_x = \frac{T}{2\omega\sin\varphi}. \tag{15}$$

Since the above discussion applies to any velocity, between air and earth in any direction, let, as we may, $w'a'$, Fig. 6, be the direction and velocity of the surface wind, and let i be the inclination angle, or angle between the direction of the "surface wind" (wind at bottom of region of constant eddy viscosity, say 10 metres above the surface) and the direction of the isobar, or direction of the gradient wind. Then, on the assumption that the viscosity is constant up to the gradient-direction level, and from there on zero, the gradient velocity is given by $w'a$, determined by drawing $a'a$ so as to make the angle $w'a'a$ 135°.

From Fig. 6, it also is evident that the surface wind W_s is given, in terms of the gradient wind W_g by the equation

$$W_s = W_g(\cos i - \sin i), \tag{16}$$

and the drift wind, W_d, by the equation

$$W_d = W_g\sin i\cdot\sqrt{2}. \tag{17}$$

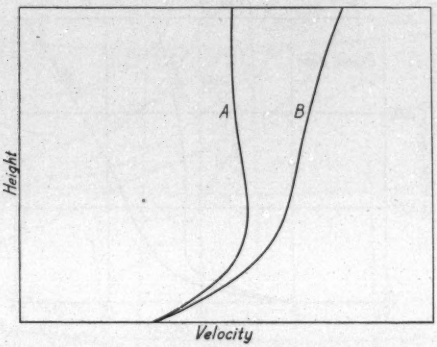
The figure also shows that, theoretically, the wind attains gradient velocity both below and above the level of gradient direction, and that at this level the velocity is distinctly in excess of the gradient value. All these surprising deductions have actually been observed.

Since H, the height of the gradient-direction wind, is given by observation, we have, from (14), in known terms

$$\mu = 16\, H^3 \rho \omega \sin \varphi / 9\pi^2. \qquad (18)$$

Clearly, then, the direction and velocity of the wind at different heights up to the level of gradient direction furnishes, as indicated by Fig. 6, a means of determining whether or not μ is essentially constant. This has been done, and the assumption that normally μ is substantially constant with height fully sustained,[10]

FIG. 7.



Theoretical relation of wind velocity to height; *A*, gradient per unit mass, constant; *B*, gradient per unit mass increasing linearly with height.

however much it may vary with the roughness of the surface and velocity of the wind.

If the driving forces X, Y, per unit mass, hence the gradient wind, are the same at all levels, as above assumed, then the speed of the actual wind varies with height substantially as indicated by curve *A*, summer type, Fig. 7. If, however, these forces increase linearly with height, this speed will vary as indicated by curve *B*, winter type, Fig. 7.

OBSERVATIONS.

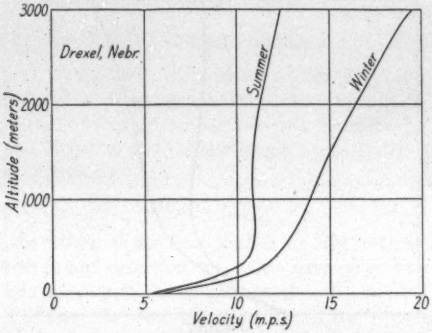
The foregoing, like mathematical analyses in general, tells us unequivocally not what may happen but what must happen, provided, of course, the premises are both accurate and complete.

[10] TAYLOR, *Phil. Trans.*, A215, p. 1, 1915; WHIPPLE, *Q. J. Roy. Met. Soc.*, 46, 39, 1920.

But certain of the above primary assumptions are only approximately true; hence in this case, too, as is the rule, it is necessary to compare the theoretical deductions with the observed facts—the "must be" with the "is."

The averages of the wind velocities at various heights in the lower atmosphere, from observations made daily, or nearly so, over a period of several months, give a curve of the same general type as the theoretical ones shown in Fig. 7. This is well illustrated by Fig. 8, a typical example from many, based on

FIG. 8.

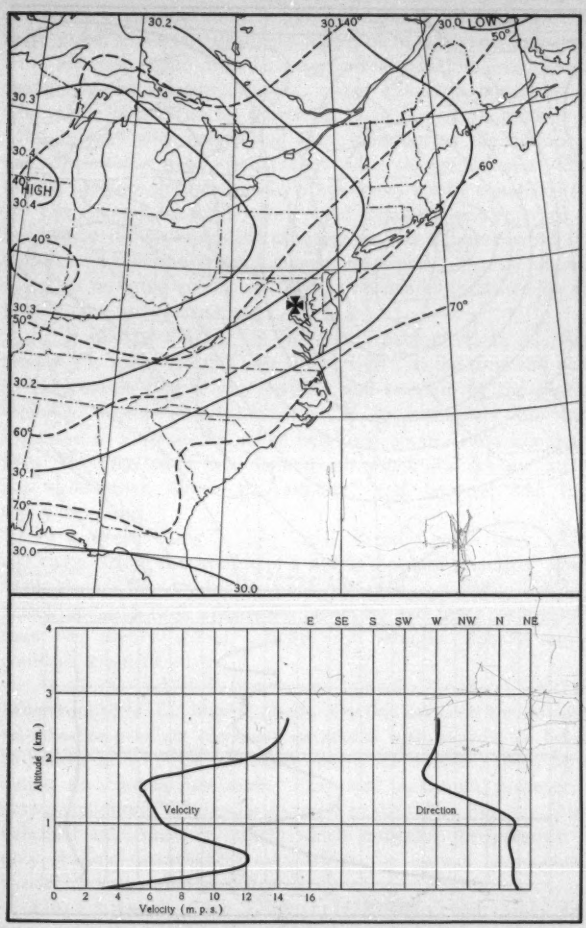


Average, over several years, wind velocities at all heights, from surface to 3 kilometres, at Drexel, Neb.

observations covering several years at Drexel, Neb., and kindly furnished by W. R. Gregg, U. S. Weather Bureau. Clearly, then, so far as change of velocity is concerned, the assumptions on which the theoretical analysis is based seem to be substantially correct. And the same is true of the wind direction, since, as long known, the angle between this direction and that of the current isobar decreases with increase of elevation, to approximately zero at half a kilometre, or thereabouts, above the surface.

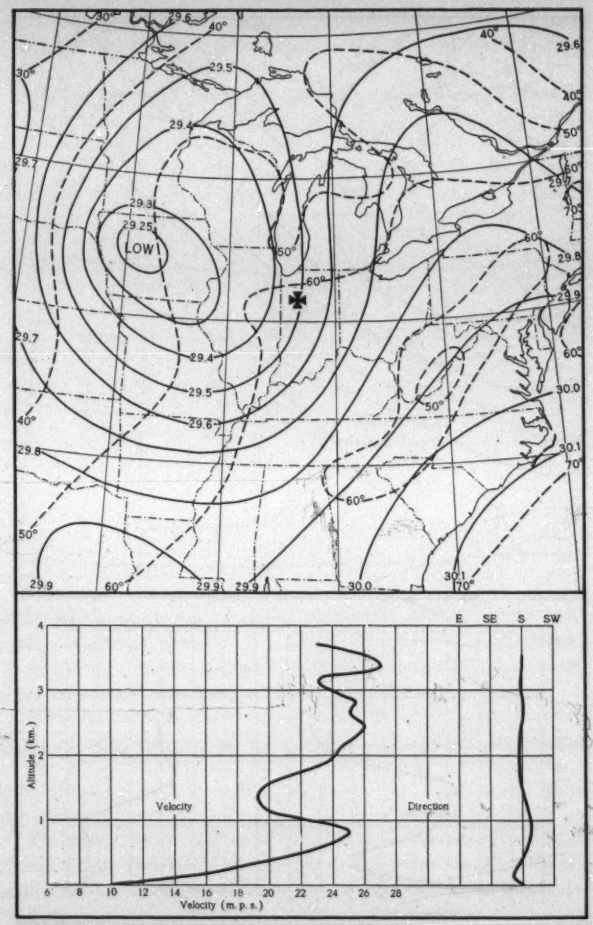
On many individual days a well-defined maximum velocity occurs at the height of about half a kilometre, and an equally pronounced minimum—often even less than that at the surface—near the one-kilometre level. This great decrease of velocity commonly is accompanied by, and owing to, a change of direction. Thus, on the poleward border of a cyclone, or equatorward bor-

FIG. 9.



Relation of wind to height in the southeastern border of a shallow "High." Washington D. C., 8 A. M. (75th meridian), September 14, 1923.

FIG. 10.



Relation of wind to height in the forward portion of a deep "Low." Royal Center, Ind., 8 A. M. (75th meridian), April 21, 1923.

der of an anticyclone, the wind changes from easterly near the surface to westerly at some height, often about one kilometre. In these cases, as also in all others where there is a great change in wind direction, there must be a marked drop, at the level of such change, in the velocity. Again, where a shallow border of an anticyclone is overrun by a cyclone, there is first an increase of wind velocity with height and then, on entering the cyclone, a marked decrease, even when there is little change either in direction or pressure gradient, as fully accounted for by equation (3).

The changes of wind velocity and direction here referred to, incident to the superposition of more or less different wind systems, merit illustration by particular examples. Typical of such cases, all morning conditions, and at the places indicated on the figures by a heavy cross, are:

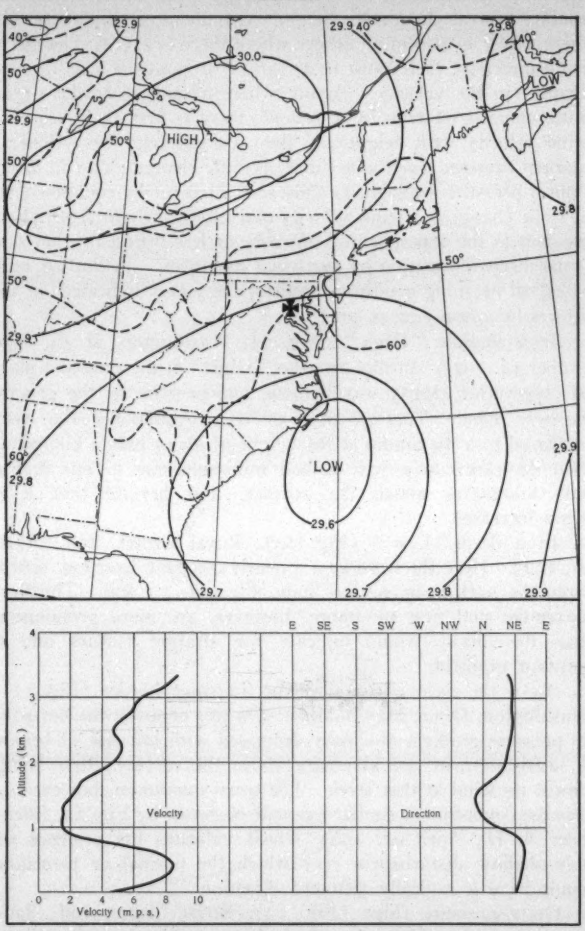
In a shallow "High" (Fig. 9), Washington, D. C., September 14, 1923. In this case the "High" at the time and place of observation clearly was shallow, and overrun by the general westerly wind. The velocity, as is so commonly the case, increased to a maximum at the height of about half a kilometre, then decreased to a well-defined minimum one to one and a half kilometres above the surface, and beyond that level again increased.

In a deep "Low" (Fig. 10), Royal Center, Ind., April 21, 1923. Here the wind kept a nearly constant direction, south, from the surface up to the limit observed, 3.7 km. The first maximum and first minimum, however, are more pronounced than the theory would indicate for straight isobars and a constant gradient.

Along the cyclone to anticyclone transition border (Fig. 11), Washington, D. C., May 6, 1923. On this occasion the horizontal pressure gradient obviously decreased with increase of height to nearly zero at one kilometre above the surface, there being almost no wind at that level. The usual maximum, however, is very pronounced. A similar example is shown by Fig. 12, Ellendale, N. D., April 22, 1924, which indicates the presence of only shallow disturbances over which the normal or planetary winds have a radically different direction.

On a pressure ridge (Fig. 13), Royal Center, Ind., January 17, 1923. Here the wind changed direction 180° in a kilometre and a half, and necessarily therefore fell from a well-

FIG. 11.



Relation of wind to height on the border between a "High" and a "Low," "High" to northwest. Washington, D. C., 8 A. M. (75th meridian), May 6, 1923.

defined maximum to an almost zero minimum. Apparently the disturbed layer was shallow and overrun by the normal circulation.

In a pressure trough (Fig. 14) Royal Center, Ind., March 18, 1923. In this case a small secondary Low in the trough seemed to control through the first quarter to half kilometre, giving the usual first velocity maximum. Next above this level, the pressure gradient was feeble with the winds from a different direction and very light. At the height of a kilometre and a half, or thereabouts, the forward anticyclone came into control, and quickly gave strong winds owing to the markedly different temperatures on the opposite sides of the trough.

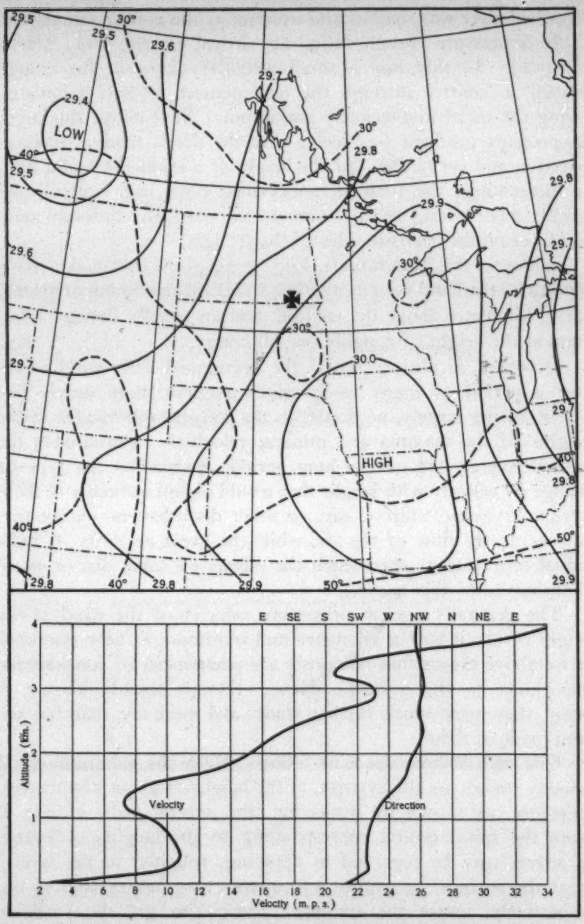
These several illustrations, Figs. 9–14, show that under many conditions the wind velocity reaches a decided maximum at around half a kilometre above the surface, and an equally decided minimum at the height of roughly one kilometre.

However, as already stated, the average of daily wind values over a period of many weeks gives a curve more nearly like Fig. 8, owing largely, no doubt, to the considerable ranges in the heights of the maxima and minima velocities. Presumably the general average, if over a long period, approaches the type of change of velocity with height that would obtain normally if there were no cyclonic, anticyclonic, or other disturbances, except turbulence, in the flow of the air, while the great majority of individual observations show each the effects of some one or more disturbances of this nature.

The generally present maximum velocity of the wind at the height of about half a kilometre and minimum at near one kilometre above the surface obviously are phenomena of considerable importance to the aviator. Hence, though already known to many, they merit much further study, and more use than has yet been made of them.

One such obvious use is as follows: Since the maximum wind velocity occurs, on the average, at the height of about 500 metres, therefore, as shown by inspection, the several radii in Fig. 6 from the spiral centre, corresponding to the heights 0, $\pi/10a$, *et cetera,* may be regarded as applying, roughly, to the levels: Near the surface, 75 metres, 150 metres, 225 metres, and so on, respectively, above the surface. Hence, to get the probable direction and speed of the wind at any level up to 500 metres, draw a straight line, such as $w'a'$, Fig. 6, which shall represent

FIG. 12.



Relation of wind to height on the border between a "High" and a "Low," "High" to southeast. Ellendale, N. D., 8 A. M. (75th meridian), April 22, 1924.

the surface wind; at the end a' draw another straight line, 135° from $w'a'$, and to the right (for the northern hemisphere) as viewed from w'; and make $i = 20°$ for water, or 30° for land. Next, lay off about the spiral centre, wa, a series of radii at steps of 18°, or any other convenient interval from the initial radius aa', and connect a' with a by means of a spiral so drawn that it shall cut all radii from a at 45°. To this end it is convenient to compute the relative lengths of the several radii and lay them off accordingly before drawing the spiral. From this construction one has: Surface wind, $w'a'$; gradient wind, $w'a$; probable wind at the heights of 75 metres, 150 metres, and so on, w' to terminus of proper radius. In Fig. 6, $w'a''$ represents the direction and velocity of the wind 300 metres above the surface, of course in terms of the surface velocity. That is, if the surface velocity is v, the approximate average velocity 300 metres above the surface is

$$V = v \frac{w'a''}{w'a'}$$

The velocities at other heights are similarly obtained.

Or, if one prefers, he may use for the wind velocities a previously computed table, such as the following:

Approximate Average Wind Velocities at Different Heights

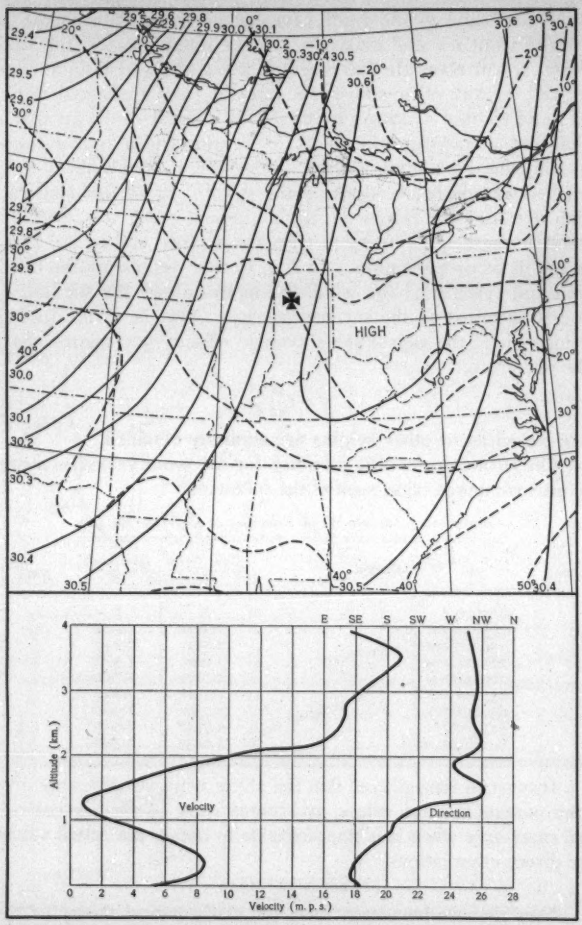
Height.	Over Water $i = 20°$.	Over Land $i = 30°$.
Surface	v	v
75 metres	1.305v	1.729v
150 metres	1.512v	2.232v
225 metres	1.642v	2.561v
300 metres	1.717v	2.758v
375 metres	1.751v	2.862v
450 metres	1.759v	2.902v
525 metres	1.752v	2.902v
Gradient level	1.673v	2.732v

It must be remembered that the above wind velocities are only approximate average values, and therefore to be used in individual cases only when it is impracticable to obtain the actual values by direct observations.

THEORY, PHYSICAL.

Now that we have seen from the mathematical theory of the way of the wind what, under certain conditions, must happen, and from the observations that what "must happen" really, in

FIG. 13.



Relation of wind to height on a high pressure ridge. Royal Center, Ind., 8 A. M. (75th meridian), January 17, 1923.

effect, does happen, there remains only the necessity of explaining why it happens—of giving the common sense or physics of it, thereby supplementing the logical proof and observational testimony by a peaceful understanding. To this end the exactly similar problem, as already explained, of finding the steady state of initially quiet deep water, as induced by a wind of constant direction and velocity, will be considered, being easier to visualize, presumably, than the action of a water current on initially still air.

Let, then, aa', Fig. 15, represent the steady direction and velocity of the surface air. The water, being free to flow, and on a rotating sphere, will deflect from the wind direction—to the right in the northern hemisphere. Let ww' be the direction and velocity of the surface water. Numerically, at latitude ϕ,

$$ww' = 7.9 \times 10^{-3}\ aa'/\sqrt{\sin\varphi}$$

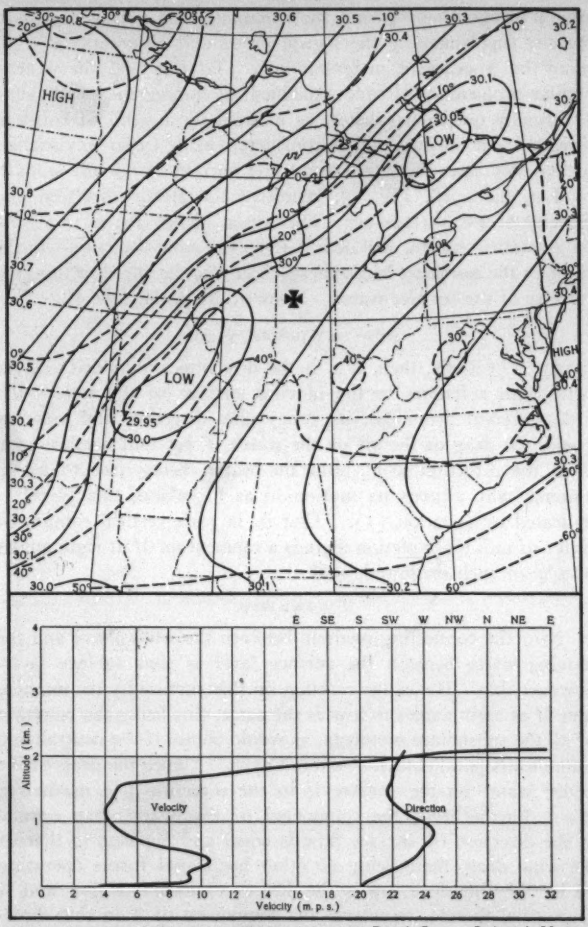
nearly.[11] Clearly, then, $w'a'$ is the direction and velocity of the wind with reference to the moving surface of the water—but little different from aa', its geographic direction and velocity. Hence the drag of the air on the water, T per unit surface area, is in the direction $w'a'$. But the water, being free to move, automatically adjusts its motion so as to balance this force, as indicated by equation (1). That is, in each vertical column of water of unit cross-section there is a momentum M at right angles to $w'a'$ of such magnitude that

$$T = 2M\omega \sin\varphi.$$

Now the connecting medium between the wind above and the moving water beneath the surface layer is that surface layer, however thin. Hence the reaction on this surface by the momentum M at right angles to $w'a'$ is the same, this being the resultant of all the subsurface momenta, as would obtain if the neutralizing components parallel to $w'a'$ did not exist. Hence the drag of the under water on the surface is in the direction $w'b$ normal to $w'a'$. Furthermore, the component of this water drag normal to the direction of surface flow is equal and opposite to that of the wind drag, there being no other horizontal forces operating on it. If, therefore, wp is the direction of surface flow and if pc, normal thereto, represents the component of T in that direc-

[11] DURST: *Q. J. Roy. Met. Soc.*, 50, p. 115, 1924.

FIG. 14.



Relation of wind to height in a low-pressure trough. Royal Center, Ind., 8 A. M. (75th meridian), March 18, 1923.

tion, then *pb*, equal and opposite to *pc*, similarly represents the component of the water drag on the surface at right angles to the direction of flow.

From the similarity of triangles and the fact that *bw'a'* is a right angle, it follows that *pw'a'* is half a right angle. Hence, under the conditions assumed as to steady winds and initially still deep water, the final direction of surface drift makes an angle of 45° to the direction of the wind with reference to the water surface—to the right in the northern hemisphere, to the left in the southern.

Consider next the water as made up of separate layers, each moving as a solid and connected to its neighbors by interfacial viscosity, and let *ww''* be the direction and velocity of the second layer. Clearly, then *w''w'* is the direction and velocity of the first or surface layer with respect to the second. Also, exactly as before, we find that the drift of this second layer is 45° to the right (northern hemisphere) of the direction of the first layer with respect to the second.

In this manner any depth may be reached, however thin the separate layers. Hence the projection of the envelop of the radii vectors of the water drifts onto the surface is a 45° (or 135°) equiangular spiral about any common starting point of wind and water.

Since the above directional relations are independent of velocity, it follows that the amount of spiralling is directly proportional to depth, provided the viscosity, here owing to turbulence convection, is constant. Hence, from the direction and velocity of the surface drift and of the drift at any known depth the movement of the water at any other depth may be determined graphically. Also from these observed drifts the viscosity readily can be determined.

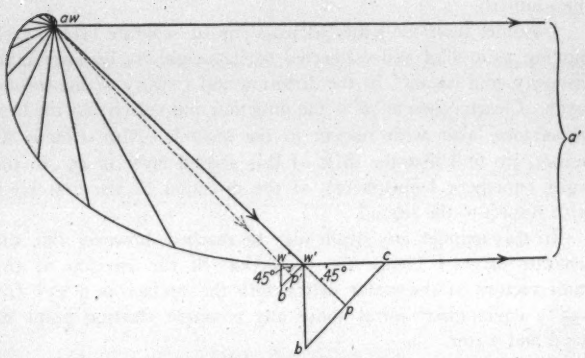
Exactly similar conclusions, arrived at in precisely the same way, apply to the atmosphere, as already explained.

OTHER DISTURBING FACTORS.

As stated in the first paragraph of this paper, there are many factors, in addition to the major ones already discussed, that in some measure affect the way of the wind: (1) Forests, for instance, increase the turbulence of the lower air, hence also the

deviation of the surface wind from the direction of the current isobar. (2) Hills and mountains provoke eddies and, in many cases, set up waves, or giant riffles, in the crossing currents. (3) Different types of surface, such as land and water, barren and vegetated, soil and snow, etc., lead to unequal heating and cooling of the lower air, a condition that generates many a breeze —land, sea, mountain, valley, lake, forest, and numerous others, both named and unnamed. (4) The presence in the air of water

FIG. 15.



Ocean drift induced by a steady wind.

vapor in varying amounts leads to the formation of fogs and clouds, which in turn greatly alter the distribution of surface temperature and thereby affect the winds. It also, on condensing, liberates much heat, and as the cloud, or falling rain, is evaporated, heat in great quantity is locally absorbed. Hence the water vapor of the atmosphere markedly modifies not only local blasts and breezes, but every wind that blows.

Truly, then, owing to these, and still other, minor disturbances, and especially to the two major ones, the rotation of the earth and the turbulence of the atmosphere, the way of the wind is devious and strange. It is not past following, but that following is exceedingly difficult, if not quite impossible, without the guidance both of sound physical concepts and accurate mathematical analysis.

MAGNETIZATION OF SPECTRUM LINES. REMINISCENCES AND PROSPECTS.*

BY

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YOUR Secretary told me that it is the custom for Franklin Medalists to prepare a paper which is read at the occasion of the formal presentation of the Medal. I therefore have arranged to give you a short review, partly historical, about my subject. This is clearly indicated because the terms of the award, by which you have done me so significant an honor, state that it is made for my contributions in the field of magneto-optics and particularly for my discovery of the effect of a magnetic field upon the frequencies of the light from a radiating source.

The science of physics has made such unexpected and great advances during the last thirty years that it is rather difficult to reconstruct our mental attitude to the time of the discovery of the effect of magnetism on light frequency. For me this task is made easier now that my personal recollections are supplemented by publications issued at the twenty-fifth anniversary of the effect in 1921 by my friends, Lorentz and Kamerlingh Onnes, in the Dutch physical review, *Physica,* Vol. 1, the reprint (in the *Electrician* of February 17, 1922) of two communications by Oliver Lodge, which first appeared in the *Electrician* in 1897, and reproduced with some interesting notes; finally, by a paper by Sommerfeld and Back in *Die Naturwissenschaften* of November 11, 1921. The first observation of the effect was made in August, 1896. I was at that time a research student in the Physical Laboratory, Leiden, under Prof. Kamerlingh Onnes. The thought to submit a source of light to the influence of magnetism occurred to me during a quantitative investigation of the effect discovered by Kerr, concerning the light reflected by magnetized mirrors. To this kind of precision measurements I was introduced by Doctor Sissingh.

In considering the different possibilities of explaining the

* Presented at the Stated Meeting held Wednesday, May 20, 1925.

phenomena exhibited by magnetized mirrors, the question suggested itself to me whether the magnetic forces operating during the propagation and reflection of light might also influence upon the frequency of the light. This idea afterwards proved to be a sound one. Professor Onnes tells us that he was much surprised when one morning standing near the apparatus for the Kerr measurements, I mentioned the idea to him. Experiments with a sodium flame placed in a magnetic field and with a glass spectrograph only gave negative results at the time. As nothing could be predicted by theory concerning the supposed change of the sodium lines, I returned not without some irresolution to the more modest task of completing some optical measurements and measuring the absorption of electric waves in salt solutions, a subject to which I had been initiated by Prof. E. Cohn.

The idea remained, however, before my mind, and it was my ambition to try the experiment again whenever I succeeded in getting a more powerful electromagnet or a spectroscope of greater resolving power. The latter desideratum was fulfilled by the acquisition of a concave Rowland grating with 48,000 lines for the Leiden Laboratory. In the meantime the strength of my conviction had been considerably increased, so to say, by moral influence by reading Maxwell's sketch of Faraday's life. In 1862 Faraday, in an experiment said to have been his last, "endeavored, but in vain, to detect any change in the lines of the spectrum of a flame when the flame was acted on by a powerful magnet." As already mentioned, in August, 1896, I was successful.

My arrangements were simple enough. A slit of variable width, the grating of 10-foot radius and an eyepiece were placed on three entirely separated columns of freestone, which were interconnected by their being fixed on the large pier of the laboratory. The intensity of the magnetic field was about 10 kilogauss. In the first experiments the observation was made at right angles to the lines of force. Use was made of a Bunsen flame, soon interchanged for a gas flame fed with oxygen in order to secure greater stability of the flame between the poles. The yellow sodium lines and the red lithium line were seen to broaden when the magnet was excited.

All care was taken to exclude the danger of spurious and commonplace causes of the effect. So I arranged a porcelain tube containing sodium between the poles, and intensely heated at that

place, and I traversed a beam of electric arc light through it into the grating spectroscope. The dark absorption sodium lines were observed and made of uniform width by rotating the tube on its axis. The same kind of broadening was observed as with the emission lines when the field was made. I then considered the fact, *viz.*, " that by the action of magnetism on the free vibrations of the atoms, which are the cause of the line-spectrum, other vibrations of changed period must be superposed " established and made a communication for the Amsterdam Academy of Sciences, to which it was presented by Prof. Kamerlingh Onnes in the meeting of October 31, 1896.

It was a most fortunate circumstance that the theory of electrons was just now born. Prof. H. A. Lorentz had laid its mathematical foundations and had given its general results concerning the electrical and optical phenomena in resting and moving bodies. To him I told my discovery and he at once informed me, with some caution, that it agreed with his theoretical views concerning radiation, and that certain polarization phenomena ought to be present. If I looked across the lines of force at the flame I would see the extreme edges of the broadened sodium lines plane-polarized, with the plane of polarization parallel to the lines of force. But with perforated poles I should find the broadened lines circularly polarized in opposite sense on the two sides of the line. Lorentz, too, sketched the mathematical theory of the phenomenon. Before I began to verify these conclusions, I calculated the magnitude of the effects to be expected and like every one else at the time, including Lorentz, I considered that the radiating " ion " must have an $e/m = 10^4$. This, however, would have made it impossible to observe any of the predicted polarizations. Then followed most exciting days. They ended with a complete confirmation of Lorentz's predictions.

The polarizations could be confirmed. The most convincing experiment was that with the perforated poles. The change of sign of the circular polarization with reversal of the current made itself manifest when the analyzer was rightly chosen by a motion of spectral line.

From the measured data I calculated by Lorentz's theory e/m of the order 10^7. As Professor Sommerfeld says: " With Lorentz's theory the Zeeman effect came into its quantitative state." This number, 10^7, was the first value found for the

exceedingly important quantity e/m in an optical problem, and something entirely new in 1896. At about the same time the same ratio was found in the experiments of J. J. Thomson and of P. Lenard on the cathode rays. From the magneto-optical effect also the sign of the charge of the vibrating mass was determined. In this determination of the sign I made "a curious and instructive error" as Sir Oliver Lodge rightly comments. The error was speedily corrected by myself. It shows the uncertainty of everybody then about the nature of radiating particle.

In 1897 I was appointed lecturer and soon afterwards extraordinary professor in the University of Amsterdam, at the suggestion of van der Waals. I began my work there by a re-criticism of my experiments and this gave me the true fact concerning the sign of what we now call the electron.

In Amsterdam I had to work with a 2¼-inch grating of rather feeble intensity, having 6 feet radius and 14.438 lines per inch. The arrangement was rather unsatisfactory. Grating, slit and camera were separately placed on a large wooden table in one of the two rooms of the laboratory of the second floor which were the only ones at my disposal. Progress was very slow. Every visitor to the upper floor of the laboratory, a movement of the observer who watched the spark, and the traffic in two adjacent streets gave rise to almost constant disturbances.

The current in the dynamo was often inconstant owing to being used indiscriminately at other places. Of thirty photographs, at most one could be used. The important conclusion could, however, be drawn that e/m is not equal for different lines, and that different series behave differently in the magnetic field.

In the course of my investigation it appeared that other observers were in the field working under far more favorable circumstances. No hope being left of obtaining a more stable arrangement for want of funds and of space I was obliged to abandon for the time my endeavors to photograph a whole spectrum in the magnetic field.

Not before 1907 were funds available for a new grating room and the rigid mounting which has served me in various experiments.

Happily in 1898 my attention was directed to investigations for which somewhat less stability was sufficient. I refer here to experiments concerning the phenomena which accompany mag-

netic resolution of the absorption lines or the inverse effect. In the neighborhood of the inverse components, magnetic linear and circular double refraction may be observed. Metallic vapors may exhibit in this way very strong manifestations of effects which are entirely out of our range of observation in parts of the spectrum out of the immediate control of absorption lines.

The theory of these phenomena, so closely allied to the magnetic resolution, has been developed by Voigt. To Woldemar Voigt, who died in 1919, I was related by personal friendship and to him I owe much inspiration in this domain. The most beautiful fruit of Voigt's studies in magneto-optics is, according to Professor Sommerfeld, the theory of the magnetic type of the two sodium lines. I quite agree with this opinion about Voigt's calculations, which were put by Sommerfeld into a formally most perfect and simple garb, but I myself profited most by the correspondence with Voigt when all was still in a tentative form, and when I was associated with my pupil, Doctor Hallo, for measuring the rotation of the plane of polarization in the vicinity of the sodium lines. Passing over many other investigations, I now want to say something about our prospects in the investigation of the magnetic resolution. The Rutherford-Bohr model of the atom and Bohr's theory of spectra are full of promise for the explanation of the facts of the magnetic resolution of the spectrum lines. Applications of the quantum theory of spectra in the hands of Bohr, Sommerfeld and Debye have illuminated the problems under review. The fundamental idea of Bohr's theory that each spectral line is due to the transition between two stable states of the atom, or, otherwise expressed, may be calculated as the difference of two terms, has been abundantly confirmed by the magnetic separation of spectral lines.

The original theory of Lorentz had to be abandoned. We must not forget, however, that the theory of the magnetic separation of the hydrogen lines according to the quantum theory and with the aid of the principle of correspondence, exhibits a profound analogy with Lorentz's original ideas.

To Landé we are indebted for an admirable scheme which enables us to predict all complex magnetic resolutions by simple formulæ, containing certain quantum numbers characterizing the spectral series to which the line of which we want to know the resolution belongs. The study of the magnetic resolution patterns

gives us a key to the structure of spectra, which at both sides of the Atlantic is now being amply used.

In my book on "Magneto-optics" (MacMillan, 1913), I said, "It is now easily realized that the concrete triple event of narrow spectrum lines, combined with great resolving power of the analyzing contrivance and with strong magnetic field, is decisive for success, if success can be reached, in the magnetic resolution of the lines. The historical development of the subject shows, however, how late these three elements were combined."

A few words may be added concerning the most recent progress along each of these three tracks. A most efficient lamp for obtaining very narrow lines of metallic vapors and ordinary gases has been constructed by Doctor Back, of Tübingen. In developing the vacuum arc used by Michelson in early work on the magnetic effect and the vibration of Fabry and Perot, Doctor Back's lamp is now our most important aid in the observation of the magnetic resolution patterns. The success of Back's beautiful work on beryllium, manganese and other metals is largely due to the new construction. In a slightly different form, due to Mr. van der Mark, it was applied by van der Mark and Goudsmit in my laboratory. In a joint paper with these authors the analysis of scandium is given. Hansen and Jakobsen constructed and used with success a discharge lamp of special design which enabled the discharge to pass through the gas parallel to the lines of force, a condition of first importance in all these apparatus.

After the discovery of the magnetic effect different kinds of powerful spectroscopes have been invented, connected with the names of Michelson, Fabry and Perot, Lummer. For the detailed study of the behavior of single lines these apparatus have been successfully used, and for the very highest resolving power they are the only available ones. The concave grating is, however, our most efficient instrument for disentangling extensive spectra with complicated resolution patterns. There is no difficulty of interpretation as occurs with interference apparatus.

The third essential thing for obtaining resolution patterns as perfect as possible is a homogeneous strong magnetic field. The electromagnets of the du Bois and of the Weiss type give a magnetic field of 40,000 gauss with a distance of 3½ mm. of the polar pieces and a diameter of 8 mm. of the end planes.

Deslandres in 1914 constructed a new type of electromagnet.

With currents of 3000 and 5000 amperes and intense water cooling, he got the strongest statical field obtained thus far. By the magnetic resolution of zinc lines its strength was determined 63,700 gauss.

On the Mount Wilson Observatory a field of high strength throughout a space of 2 inches in diameter by 4 inches in length is obtained by means of a water-cooled solenoid without any iron. It requires approximately 400 kw. to give a field of 45,000 gauss in such a space. Experiments for the construction of a large-size electromagnet are being made under the direction of Professor Cotton. His apparatus will be more costly but the necessary electrical power is only of the order of 100 kw. The apparatus thus far considered give statical fields. Kapitza has given an account of a method for obtaining magnetic fields of short duration (1/100 of a second) of strengths up to half a million gauss. Kapitza and Skinner have obtained a spectrum photograph by means of a quartz spectrograph, the intensity of the spark being such that one spark sufficed.

The longitudinal effect in fields of about 130,000 gauss of some aluminum and calcium lines were observed. It would certainly be of great importance when the luminous intensity could be made sufficient to allow of the use of the great resolving power of a concave grating of moderate radius of curvature.

All these new appliances will be of great service for further examining in detail the behavior of the intra-atomic processes under magnetic forces. I must close this brief sketch of the origin and outcome of some of my investigations in magneto-optics, a chapter of physics which by the coöperation of physicists of all nations has become larger, more important and exhibiting a richer variety of phenomena than I could have dreamed of at the beginning of this century.

A Powerful Source of Short Sound Waves. M. HOLTZMANN. (*Phys. Zeit.*, Jan. 15, 1925.)—For the emission of notes of high pitch and of consequently short wave-length the customary source, the Galton whistle, is unsatisfactory on account of the feebleness of its emission and of the presence of overtones. A better source has been found in a glass tube open at one end, but closed at the other by a bulb blown on it. This tube is clamped at its middle and is rubbed lengthwise by an endless belt which presses against it and is driven, by a motor, so as to travel with a speed of about 50 cm. per sec. The

belt is composite in structure, being made up of leather, rubber and silk, where it touches the glass. Thus waves of 1 cm. length are obtained and their intensity is great, amounting to 150 times that of the product of the Galton whistle. This article comes from the Laboratory of Experimental Geophysics in Leningrad, and it was there that the improved source was applied to a study of the absorption of sound waves in a smoky atmosphere. Though the results are not sufficiently accurate to serve as a test for the theory derived by Lord Rayleigh, they confirm it in its broad outlines. For example, in an atmosphere containing .0000073 g. of smoke per c.c. the percentages of energy absorbed by a layer 56 cm. thick were 70, 64, 58, 49 and 24 for wave-lengths of 1.5, 2.7, 3.5, 4.4 and 6.5 cm., respectively. G. F. S.

Thomas Beddoes: A Neglected Chemist.—T. W. JONES (*Sci. Prog.*, 1925, **19**, 628–639) has written an interesting account of the life and work of Thomas Beddoes who lived from 1760 to 1808. He was a graduate of Oxford in both arts and medicine, and lectured on chemistry in that university. Certain of his innovations are still in use: The use of ice in fever, and the use of fresh meat to prevent sea scurvy. Beddoes translated the chemical treatises of Scheele and Bergman into English, and introduced Mayow ,and Humphry Davy to the English scientific public. He studied the physiological action of oxygen, hydrogen, carbon dioxide, nitrous oxide, and water-gas on animals. He recognized that iron in animals and plants, and manganese in plants have an organic function. He was apparently the first to recognize the similarity between the alkalies and the alkaline earths, and suggested that the alkalies are unable to combine with oxygen because of "some peculiarity of the union of their elements or because they are already combined with oxygen." This suggestion foreshadowed the decomposition of the alkalies by his pupil, Davy. Beddoes was also a pioneer in preventive medicine. J. S. H.

Classification of the Lipins.—VICTOR E. LEVINE, of Creighton University (*Jour. Chem. Education*, 1925, ii, 181–183), has suggested a new classification of the lipins, or fats and related compounds. He recognizes true lipins and lipoids. The true lipins are subdivided into simple, conjugated, and derived. The simple lipins yield only fatty acids and either glycerol or a monohydric alcohol of high atomic weight on hydrolysis; they include the fats, fatty oils, and waxes. The conjugated lipins, on hydrolysis, yield fatty acid, an alcohol, and a conjugated compound, such as phosphoric acid, sulphuric acid, carbohydrate, amino acid, or nitrogenous organic base; lecithin, protagon, and lipochrome, the fat pigment, are typical conjugated lipins. The derived lipins include the fatty acids, alcohols, and organic bases which are formed on the hydrolysis of simple or conjugate lipins. The lipoids include the essential oils and the sterols. The later are alcohols of the terpene series, *e.g.*, cholesterol and phytosterol. J. S. H.

THE MECHANICAL, THERMAL AND OPTICAL PROPERTIES OF FUSED SILICA.*[1]

BY

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FUSED silica, or silica which has been fused and cooled, is also known as silica glass or fused quartz. It is no new thing, for early workers with the oxyhydrogen blowpipe found that rock crystal or quartz could be rendered soft and plastic and could be drawn into fine threads, and as much as thirty years ago these fine threads were applied as torsional suspensions for delicate needles in galvanometers. They were found far superior to glass or other materials as being more perfectly elastic and not subject to drift in the readings.

Despretz in 1849 formed a small tube of silica by fusing sand around a rod of carbon heated by a battery current, the rod being simply immersed in or covered by the sand.

It is about twenty-five years since the present writer began work on obtaining this most interesting product or material on a larger scale and under special conditions so that its remarkable properties might be utilized.

In England, under the leadership of Dr. R. S. Hutton, of Owen's College, Manchester, similar development was carried on upwards of twenty-five years ago, and a considerable application to chemical apparatus took place, by an organization known as the Thermal Syndicate. Much credit should be given to this organization for its truly remarkable progress in the working of silica rendered plastic by electric heating. The concentration of sulphuric acid in vessels of fused silica, arranged in cascade over a furnace flue, has fortunately relieved the industry of the incubus

*Presented at the Stated Meeting of the Institute held Wednesday, May 20, 1925.

[1] In the development of fused quartz by the Thomson Research Laboratories of the General Electric Company, Lynn, Mass., the author desires to note, at the outset, the able assistance in working out the various problems concerned, given by Dr. E. R. Berry, P. K. Devers and L. B. Miller in connection with the clear quartz work, and of Mr. H. L. Watson in the opaque or coarser variety.

of the platinum still which in the earlier years cost from $50,000 to $75,000 each and were subject to wear. Such vessels to-day would cost probably ten times as much. Besides, concentration in glass stills over a fire, sometimes used instead of the platinum still, was slow and not without great risk of breakage of the glass by heat and spilling of the corrosive hot acid, the fumes from which, when dropped into a fire or upon a hot surface, are insupportable.

It was not, however, my intention to go into details of these and other similar applications. Suffice it to say that in the laboratories of the General Electric Company at Lynn, Mass., special methods developed there have given a product or products which, by the advances on previous methods, are in some respects unique.

By careful selection of material, such as rock crystal, and proper preparation thereof, together with fusion in an electric vacuum furnace, clear masses reasonably free from bubbles are obtainable and the scale of operations can be enlarged so that pieces of many pounds in weight result. Moreover, by subjecting such fused masses to a high pressure during cooling and solidification, the bubbles retained are collapsed and made negligible.

It may be remarked here that silica does not undergo a limpid fusion, but sublimes rapidly as the temperature is raised in the attempt to increase its fluidity so as to allow bubbles of gas to rise out of it. However, the heating can be carried quickly to temperatures high enough to assist materially in clearing out volatile vapors or gases. When the use to which the material is to be applied does not call for a clear, transparent product, then the melting of such a material as fairly pure silicious sand gives a more or less opaque or translucent body full of small bubbles, and when such masses are drawn out or extended as glass is, the frothy mass becomes silky in lustre from the long, fine cavities made by the extension of the bubbles; as the drawing or blowing continues. Such a product may still be well suited to many uses where entire solidity and transparency are not demanded.

My subject is confined to the properties, mechanical, thermal and optical, of this singular material; so like a glass, but so different in many ways. To enter into details of the various methods of production and the uses of fused silica would demand more time and space than is available on this occasion.

Let us then first briefly consider the mechanical properties of

silica glass. It appears to be an ideal glass, brittle, indeed, as glass is, and hard like glass, but harder than glass; elastic like glass, but far more perfectly so. It does not, as in the case of glass, take a set under strain and but slowly recover. Like glass it cracks or breaks suddenly when strained beyond the elastic limit. It is brittle, therefore, like glass. The mechanical strength of glass is so variable with composition that it may be said that the strength of fused silica is comparable with that of the harder glasses.

A tuning-fork made of fused silica is remarkably persistent in vibration, more so than is the case with other materials. Silica glass is, therefore, a highly elastic solid. In its vibration almost negligible internal work is done in dissipating the energy of its vibration. It is, therefore, admirably adapted to the construction of standard pitch tuning-forks, especially so in view of the fact that the rate of vibration can be adjusted by grinding without, as with steel forks, involving a change in properties or vibration rate due to heating, which, followed by cooling after adjustment, raises the pitch to a false value.

A piece of the fused mass can be formed readily by grinding, as by a carborundum wheel, for its hardness, though superior to that of most glasses, is still much less than that of carborundum. Again the grinding can be done dry, as there is no danger of fracture by unequal heating.

This brings us to speak of a property of fused silica, a thermal property which is perhaps the most remarkable of all its properties, *viz.*, the almost negligible temperature coefficient of expansion. It is this property which in the case of the tuning-fork allows adjustment by grinding, which operation, of course, raises the temperature without disturbing the rate of vibration appreciably. It is this property of low expansion which saves it from cracking when ground by a rapidly moving wheel. Heat is, of course, generated in the process, but it does not bring about unequal strains as with glass, and so cause breakage. The experiment of heating the end of a rod of the material to a white heat and plunging it into cold water is well known not to result in any fracture. Heat may be suddenly applied to such a rod with equal impunity. Chemical vessels made of it do not crack on the application of sudden heat, even if their thickness is great. The explanation is, of course, that the actual change

of dimensions occurring by change of temperature is well within the elastic limit. Actual measurement of the coefficient of expansion taken at 200° C. gives 518×10^{-9}. A rough expression is the statement that it has about 1/17 the expansion per degree that platinum possesses. While it is found to expand at a slightly increased rate as its temperature rises, still the dimensional increase by heating, even over a range of 1000° C. from ordinary temperatures, is very small. A rod a metre long will increase its length about 1/2000 part or about one-half a millimetre, and will shrink in length the same amount in a fall of 1000° C. This is very different from the behavior of rock crystal or crystalline quartz, the mineral form of nearly pure silica, as its expansion is on an average about twenty times as great. Moreover, crystal quartz as heated expands unevenly according to the different axes of the crystal. The usual form of crystal is the hexagonal prism so characteristic of rock crystal. Along the main axis or length of the prism the expansion is less by nearly one-half of what it is in the direction transverse to such axis. In the former case the coefficient is 781×10^{-8}, or a little less than one part in 125,000 per degree C. For the transverse direction it is given as 1410×10^{-8}, or about one part in 70,000. As we have seen, the expansion of silica which has been fused is less than one part in 2,000,000 per degree C. These values refer, of course, to units of length. A nearly pure silica when gradually heated is transformed to crystals of crystobalite and finally to tridymite. Particles of a granular mass begin to fuse together at about 1400° C., undergoing a gradual softening. Specimens are rarely quite pure, and it is thought that even so little as one-fifth of 1 per cent. of an impurity more fusible than the purest silica may influence the softening. It can hardly be called melting, for the material seems to have no definite melting point. At a temperature as high as 1750° C. it begins to sublime, vapors are freely given off and condense as a white smoke or fume, while the silica still remains somewhat viscous so that bubbles only rise slowly through it.

This is expressed by saying that the vapor tension of silica when at a temperature of from 1700° to 1800° has attained a considerable value. But this vapor pressure or tension is indeed a useful property in some respects. If a stream of plastic silica be forced or allowed to run out of a slot or narrow opening,

bubbles contained in it are apt to break out from it and leave the strip or mass clear and free from gas or vapor bubbles, and the evolution of vapor of silica is evidently then a clearing process, much as the boiling of water gets rid of dissolved gases.

When rock crystal or other form of nearly pure quartz is heated to plastic fusion as above described, it undergoes a permanent expansion of about 17 per cent. of its original volume and cooling to ordinary temperatures involves a shrinkage of only one-fifteenth of 1 per cent., a most exceptional circumstance. There is a permanent proportional loss of density, so that it may be said that the density of the silica after fusion and cooling is about 83 per cent. of that of the quartz from which it has been formed. This fact has also an important practical bearing in that if a hollow mould of carbon be filled with quartz sand and the latter then fused, the mass after fusion will still fill the mould on account of the considerable loss of density by fusion.

The fusion of a kind of sand (which is often designated as flint-shot, and which is a very cheap variety of nearly pure silica easily made more pure by chemical washing) gives a coarse variety with most of the desirable qualities of fused silica and one which may find many uses in future work. While there are embedded in it numerous small bubbles, they are not detrimental in many cases to which the material is applicable. This coarser material is a very uniform product, and it may not be impossible that sometime in the future even cooking vessels may be made of such ware not breakable, even when thick walled, by the most sudden heating or cooling, and mechanically strong because thickness is not objectionable and heat rays are readily transmitted through the walls on account of the great transparency for invisible heat rays. The material is vitreous throughout and of course not permeable to gases or liquids. The low expansibility and freedom from breakage by sudden heating enable metal to be cast into openings in a quartz mass. Even steel has been so used.

The production of the coarser fused silica, involving as it does only silica (sand) and energy (electric) with suitable pressed carbon moulds for sustaining it during fusion, should, on the large scale, be relatively cheap. Applications of this material have already been made to the case of certain high-tension bushings to run at elevated temperatures, no other material having been found so far that will endure as does fused sand. Masses of hundreds

of pounds are readily producible, and unlike glass require no care in annealing them, for here again the low coefficient of expansion saves the situation. In the same way great masses can be reheated as desired without danger of fracture by unequal expansion.

In high-voltage transmissions of electric energy such as may employ voltages of 200,000 or more, it is possible that in the future this coarser variety of fused silica may play an important part. There are several conditions which are met by it.

(1) It can be made in any sized masses of uniform texture throughout.

(2) The process of making involves only one operation of very short duration.

(3) The heating can be rapid and the cooling likewise.

(4) No glazing is required as the material is vitreous throughout and needs no finishing.

(5) The heat of an arc playing over its surface neither makes it a conductor nor splinters it.

(6) It is completely non-hygroscopic.

(7) It can be given a thickness sufficient to render it puncture-proof for any voltage desired.

It seems reasonable to hope that with such a material at command made from sand and energy on the large scale, we may produce insulators for high-tension lines, singly capable of withstanding voltages as high as 200,000 or over. It is realized that work in this direction will necessarily be slow, as it would affect the porcelain insulator industry, established for a long period back. It is easier always for a new departure to occupy a new field than an old one.

The construction from sand fusions of high-tension terminal insulating bushings for such electric structures as transformers for high-potential transmission systems may reasonably, in my opinion, be looked forward to as providing a cheaper structure well adapted to the purpose and more uniform in character than porcelain or built-up bushings now used. The problem is similar in many respects to that of the high-tension line insulator itself.

Standards of length which are practically invariable with ordinary temperature ranges are an evident outcome of either the clear or turbid quartz fused. It is possible to construct a pendulum rod of quartz and hang upon it the metal bob so as to conserve the pendulum length during changes of temperature, and thus

secure time accuracy in a clock. I believe it possible to construct a balance wheel and hair-spring of a watch or clock of fused silica with the same benefit to it as with the pendulum. The temperature compensations would thus be shorn of difficulty and complexity.

Thermometer tubing has been made in our laboratory and thermometers of fused silica show no drift of scale in heating and cooling over a large range, a condition which is absent with glass.

The property of low expansion, or negligible coefficient of expansion, so peculiar to fused silica, finds further application in optical apparatus. In fact, it may replace glass for lenses in certain instances and also replace glass for mirrors in astronomical work or other work in physics. We are not here dealing with the actual optical properties of the material, but will deal with that part of our subject later.

Lenses used in the projecting lanterns of our moving picture houses have generally been made of glass. The condensing lenses are so near the powerful arc source of light that they are subjected to the heat so unequally that they are broken or cracked after an average of about two days' use. The refractive index for the *D*-ray is, for ordinary crown or plate glass, about 1.52. For fused silica it is close to 1.459, so that a convex lens needs to be made for a given focal length with a little deeper curve when the silica glass is used. In spite of this there is not the slightest danger of cracking and such lenses substituted for glass survive indefinitely, some having been in use for a year or so. The only deterioration is due to spattering of hot metal from the copper coating on the arc carbons. This, however, is easily removed by resurfacing, which is a comparatively simple process, only needed after long periods. With some of these lenses a curious mottled, purplish discoloration is produced after long use, which, however, is not serious, as it is removed by heating the lens over a flame for a certain time. It is suspected that the ultra-violet rays from the arc light produce the effect, so easily rectified by the heating to about 500° C., and there exists no danger of cracking in such heating.

For twenty-five years or more I have borne in mind the great desirability of procuring fused silica discs for astronomical mirrors instead of glass. Here again it is the low coefficient of

expansion and its consequences which confer so great superiority as the silica disc possesses. This may be stated under several heads.

(1) Discs require but little annealing, while with large glass discs this is a matter of great difficulty.

(2) They can be rough ground by a carborundum wheel without danger of fracture, an operation difficult with glass and rarely resorted to.

(3) The discs can be made very thick and rigid more easily than with glass.

(4) The fine grinding (or smoothing before polishing) is carried on with great facility and the surface before polishing is usually of finer grain than with glass. The fused silica is considerably harder than glass, and not so easily scratched.

(5) The polishing proceeds readily and can be carried on regardless of temperature changes. Incidentally there is less liability of scratches forming in polishing.

(6) In very accurate work, figured by polishing, as in high-grade surfaces of astronomical mirrors, the polishing and testing need not be interrupted, as with glass, by long rest periods with the mirror disc kept jacketed in felt for equalization of temperature. This is very important and involves great saving of time.

(7) In service none of the precautions against temperature variations and distortions arising therefrom are needed, and even in solar work with full sunshine on the mirrors no evil result follows.

When it is remembered that it took two years of testing and polishing for figure, involving long interruptions for equalization of temperature, to produce the 100-inch glass mirror mounted at Mount Wilson, near Pasadena, Calif., the advantage offered by fused silica is evident.

For the largest fused silica discs needed for great astronomical mirrors the construction will probably be a coarse sand disc of opaque fused quartz faced with a clear coating of relatively small thickness, which facing will be given the desired surface by grinding, polishing and figuring as usual. The feasibility of such construction has been amply proved with moderate-sized discs. The optician will also welcome the possibility of obtaining so-called flats of desired sizes, not subject to temperature distortion, while the making of accurate flat surfaces is evidently greatly facilitated. The silvering of surfaces of fused silica appears to

be no more difficult than with glass, with the advantage, however, that the former can be warmed without risk when such warming is needed to assist the formation of the silver deposit.

We come now to a consideration of the optical properties of the clear or transparent silica glass, made by the fusion of high-grade (nearly pure) quartz crystals, generally in a good vacuum, and followed by high pressure. On cooling the masses, such masses are often extruded as rod or tube or removed in solid masses called ingots, beautifully clear and colorless. These masses may then be worked up into other forms as tubing, rods, plates, etc.

Perhaps the earliest demand for fused quartz tubing was for the making of mercury arc lamps designed to yield a large output of ultra-violet light. This still constitutes an important use of clear tubing. It makes use of the property possessed by the fused quartz or silica of transparency to ultra-violet waves when the thickness traversed is small. In considerable thickness, such as many inches, it is doubtful if ultra-violet is not subject to considerable absorption.

It is indeed quite impressive to note that the rays of the ultra-violet order from a mercury arc lamp, when caused to traverse a rod of clear fused quartz eight inches long, are still capable of causing an intense reddening of the skin, even though the time of exposure be limited to one minute. Such a rod can be curved in form and internal reflection still carry the rays in the axis of the rod, a condition which has been made use of in what have been called "applicators" for delivering the rays to skin or tissues as a curative agent.

This whole matter of therapeutic value in ultra-violet radiation is a subject aside, and careful investigation is now going on in the hands of skilful research men in medical institutions to discover the limits within which such ultra-violet radiation may reasonably prove of value.

With ultra-red or invisible rays on the red end of the spectrum the case is somewhat similar but different. They traverse rods many feet in length, being confined therein by repeated internal reflection just as light passes with ease through a smooth stream of water, even if the stream be curved, a principle often applied to secure very beautiful effects from interiorly illuminated fountain jets. Much has unfortunately been made in the public

prints of this common property of transparent media in smooth circular bars in transmitting light by repeated internal reflection, from one end to the other, in straight as well as curved rods. It has been treated as if it were a peculiar property of fused quartz. In reality any fine glass, especially clear borosilicate optical crown glass exhibits the property in moderate lengths of rod, as a foot or more, very well indeed. Fused silica is, however, unique in the particular that great lengths of rod or bar are transparent. It is found that twenty-six feet is no barrier to the transmission, and the color of the emergent light is unchanged. The experiment has not yet been tried of passing a beam through a rod or a series of rods, end to end, of a length such as one hundred feet or more, but the indications are that success would follow the trial, but with some now unknown percentage of absorption, naturally. The indications are, however, that the greater loss will be from lack of perfection of the surface of the bar in its internal reflection. The surface should be optically perfect, not scattering, and entirely clean. It is probable that fused silica will rank as the most transparent solid known.

As indicated before, if heat rays are concerned instead of light, they are carried in the same way. If a bar of fused silica a foot or two in length be heated to a white heat at one end, it is not possible to place the finger either in contact with the other end or even a little away without risk of being burned by the transmitted heat rays. The rod itself, except the extremity heated, remains, of course, cold.

The transparency of the material for the higher rays, the ultra-rays of the spectrum up to wave-lengths of about 2000 Ångströms, is another property which has already been alluded to in the reference to the evacuated tubular lamp, called the mercury arc lamp, formed by an arc in mercury vapor. These lamps made of glass were fairly common some time ago and were known by the long tube full of greenish light. The glass is opaque to the higher non-luminous rays in question. Such lamps made of fused silica are intense sources of ultra-violet radiation and are in a measure dangerous at close quarters. A few moments of exposure of the eyes may be disastrous, and even the skin of the body is reddened, as if by sunburn, in a minute even at distances of a foot or two. An excessive exposure would result in a painful but fortunately superficial burn. Graduated expo-

sures have, however, shown some possibilities as a curative "dermal" stimulus. The rays are decidedly germ killing. The rays from the quartz-mercury arc lamp are found useful in sterilization, as of water, which in thin-layered streams is subjected for a few moments to such radiation. It is probable that thicknesses of several inches of most media will not allow much of these higher rays to pass. Fused silica transmits them. Window glass is practically opaque to the higher rays. Considerable attention has recently been given to these facts. In sunshine, in open air, the invisible rays may reach the skin and produce such stimulation that the assimilation of calcium and its combination with phosphorous and oxygen to form bone goes on normally. A child deprived of this open-air exposure may suffer from rickets, a disease characterized among other things by failure to form hard, bony tissues. In animals deprived of the open-air light of the sun the same tendency is noticed. Our window glass cuts off the beneficial rays. A glazed solarium fails in that respect. In our winters when shelter is too often taken behind glass to avoid exposure to cold and when heavy clothing and short days together conspire to prevent proper solarization even in the open, it is noticed that rachitic symptoms are greatly increased. In cities the sin against humanity of converting the streets and ways into sunless canyons by the erection of tall buildings is another form of smothering out the health-giving radiations.

It has, therefore, been proposed to glaze special solaria with windows of thin fused silica or fused quartz and a considerable sized experimental window has been constructed for trial in this field. The panes in this sample window were sawed from a block of clear fused quartz and afterward ground and polished, like thin plate glass. Methods are under development of obtaining such slabs by less expensive methods; slabs not necessarily of such optical perfection but sufficiently transparent to the higher rays of the sun.

Should the discovery, recently announced, that even food exposed to the sun's rays a short time before consumption confers the anti-rachitic quality upon the animal consuming it, be confirmed, it would only be necessary to cover the dish or receptacle with a fused quartz slab to ward off insects or other sources of contamination and prevent drying while the exposure to the sun is made. In recent times it has been found that the administration

of small doses of cod liver oil serves to prevent development of the disease called rickets, and that the treatment does in large measure supplant or supplement exposure to the sun's light in the open.

Investigations are being carried on in the laboratory looking to the production of an incandescent or other type of lamp in a fused silica bulb, with an output of the higher rays sufficient to render it a valuable adjunct in treatment when solar rays are absent. There is much to be learned in this fascinating field in which the physician and physiologist are most directly concerned.

The production of masses of fused silica, clear and free from internal strains, appears to present little difficulty, but there is an unwelcome disposition in some samples of the product otherwise excellent, to contain streaks or striæ, one of the bugbears of optical glass production. In optical glass-making, special stirring methods are pursued to obtain uniformity of body and absence of striæ. The fusion of silica, however, gives us at best a more or less viscous mass, difficult, on account of conditions of melting and high temperature, to stir effectively.

The best results, when one wishes to obtain masses for prisms, lenses, and such like optical apparatus, where the rays are to traverse a mass (as with optical glass) without defective or irregular refractions, are obtained by selecting good clear masses or pieces granulating them into fine fragments of nearly uniform size and placing them in a clear fused silica flask with a small opening at the top. This is heated to fusion in a good vacuum, and then subjected to high pressure. In this way masses not showing any internal streaks or striæ have been obtained. The natural application of such a product will be in constructing apparatus in which temperature changes will not disturb adjustments nor deform the optical elements of the structure, which elements serve to transmit through them or redirect the light rays by internal reflections, as distinguished from fused silica mirrors with silvered front surfaces before mentioned as ideal astronomical mirrors.

For the most refined work the melted material should be as homogeneous as possible, a condition which alone insures the absence of strains and streaks or striæ. The presence of these defects is much more serious than the existence of a few small bubbles. There are indeed certain varieties of optical glass in

which small bubbles seem to be almost always present, yet that is no bar to their use when a particular case demands them. Fortunately the expansion coefficient of fused silica being almost negligible, the problem of annealing even very large masses presents no particular difficulty. In the case of glass, the opposite is true.

It is fortunate that fairly rapid cooling is permissible, for fused silica, if kept for a time at temperatures somewhat below the softening point, undergoes (as do some varieties of glass more than others) the process of devitrification or loss of the vitreous character; increasingly as exposure to such temperatures continues. A clear mass becomes white and translucent like porcelain, and is easily fractured. A temperature around 1200° C. will result in this change of properties. It is then no longer fused silica but has lost all the properties characterizing that remarkable substance. The material is therefore not adapted to furnace linings or the making of crucibles, unless the working temperatures are well below the temperature of devitrification.

It would seem natural to expect that in the construction of scientific instruments generally, in which a change of dimensions by heat is detrimental, the silica glass would give excellent results. For example, a machine for ruling gratings of great accuracy, scarcely affected by temperature, could be constructed in which essential parts, such as the accurate screw for feeding during ruling, would be readily made from a rod of fused silica, and other parts likewise. Fine ruled gratings themselves might be made of a ruled plate of fused silica, and silvered on the back to increase the reflected light; or, in the case of ultra-violet investigations, it may be coated by known methods with silicon, a good reflector of the higher rays; which is not the case with polished metal surfaces.

Now that the methods for producing and working the material on an extended scale have been developed, the expense will naturally fall as demand rises, and new uses will doubtless be found in the future of the art and include applications of which we are not now cognizant.

When the actual physiological effects of ultra-violet rays from various known artificial sources are better known, there is little doubt that fused silica of high grade will assist materially in the application of such rays in curative treatment.

Direct Titration of the Ammonia in the Kjeldahl Method.—K. S. MARKLEY and RAYMOND M. HANN, of the U. S. Department of Agriculture (*Jour. Asso. Off. Agr. Chem.*, 1925, **8**, 455–467), have made an elaborate study of the procedure suggested by L. W. Winkler for the titration of the ammonia produced in the determination of nitrogen in organic compounds according to Kjeldahl. The ammonia is distilled as usual; but the distillate is received in 50 c.c. of 4 per cent. solution of boric acid; the ammonia is then titrated directly by means of standard sulphuric acid, using bromphenol blue (tetrabromophenolsulphonephthalein) as an indicator; the end point is the disappearance of the blue color. The boric acid serves to retain the evolved ammonia, but has no action on this indicator. The temperature of the receiver must not rise above 50° C.; otherwise ammonia is lost. The titration may be made in artificial light.

This procedure was found to be as accurate as the usual method of residual titration, in which the evolved ammonia is received in a definite volume of standard mineral acid, and the excess of this acid is titrated with standard alkaline hydroxide solution. J. S. H.

What is Coal?—The high price of coal has naturally led to the sale of inferior products. The matter was brought into legal notice by the sale in Massachusetts of material under the name of coal which was largely the refuse of the mines. A sample was submitted to the Department of Public Health which when hand-picked was found to consist of about 75 per cent. of slate and the remainder was considered coal. In March, 1923, a law was enacted according to which the permissible limits for ash are from 13 per cent. to 20 per cent., according to size, the smallest form (pea) being allowed the higher limit. In the anthracite industry, the mine-yield is graded into slate, containing less than 40 per cent. of carbon; bone, containing more than 40 per cent. and less than 60 per cent. of carbon, and coal with a proportion of carbon over 60 per cent. The data of this abstract are taken from a reprint from *The Retail Coalman*, the laboratory work having been carried out by Mrs. Eden and Messrs. Hall and March, of the Massachusetts State Board of Health. H. L.

The Isotopy of Lead. MISS B. PERRETTE. (*Comptes Rendus*, May 25, 1925.)—Ordinary lead of atomic weight 207.2 was compared with lead derived from pitchblende coming from the Belgian Congo, whose atomic weight was 206.14. The densities of these two kinds of lead were 11.336 and 11.278, respectively. Five spectral lines emanating from neutral atoms were measured. In all cases the lead of smaller atomic weight furnished lines having wave-lengths about .007 Ångström unit longer than the corresponding line from the other isotope. G. F. S.

ON RECENT ADVANCES IN WIRELESS PROPAGATION BOTH IN THEORY AND IN PRACTICE.*

BY

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ADVANCES IN PRACTICE.

THE use by Marconi of vertical reflecting wires, arranged in a parabola with the transmitting aerial in the focus line, has resulted in remarkable practical applications. In the case of a plain aerial, if 10,000 units are required to reach a given distance, then with a two-wave aperture parabolic reflector only 25 units are required, whereas with an eight-wave aperture only 1.56 units are required. Hence with power of 18 kw. on the oscillator valves and with a wave-length of 92 metres, large distances, such as from Cornwall to Buenos Aires, 5820 nautical miles, have been reached, and on this wave-length daylight signals have been reliable, and night signals stronger than were expected.

Another method which is now being employed is that of a network in a vertical plane resembling a gigantic tennis-net 3000 feet long and 300 feet high. L-shaped conductors on this net are insulated and tuned to the desired short wave-length. Behind this, at a distance of a quarter of a wave-length, is another plane network used as a reflector. By this method, instead of using lofty towers 820 feet high with 250 kw. on the aerial, involving the use of expensive insulators, it is sufficient to put about 25 kw. on the network in order to obtain equally good results, and the engineering problem is also much easier.

It is somewhat remarkable that experiments indicate that waves of a hundred metres give bad results during the daylight hours, whereas waves of thirty metres give good results by day, but bad by night. With an intermediate wave-length of about 45 metres, results are equally good both by day and by night, so that this wave-length is likely to be employed for long-distance signalling, as from Canada to Australia. It is noteworthy, too, that Macmillan in Alaska is to communicate next July with Schnell on the *Seattle*, U. S. Navy, in the antipodes, off Australia, with a wave-length selected as 20 metres. In fact, the day of the short wave-length has arrived!

* Communicated by the Author.

Experiments at Hendon, employing 700 watts with 4000 volts on the transmitters, have rendered good speech at 97 miles with a wave-length of 15 metres. Atmospherics are not troublesome, unless a thunder-storm is actually in sight, but trouble has arisen from the magnetos of automobiles emitting 15-metre waves which produce clicks in the receivers. Waves as short as 4 metres have also been tried.

At Inchkeith, in the Firth of Forth, two rotating parabolic reflectors have been mounted back to back on a vertical column with an aperture of 13 metres, which is about double the wave-length 6.3 metres. These reflectors revolve and give Morse signals for various compass bearings, so that a ship at sea is able to pick up its bearing from the land. It is probable that this method of signalling, by which a ship can obtain its own position from a revolving radiator on land, will be extended.

The amateurs have certainly developed with efficiency any bands of frequency assigned to them. It is not possible for them to use parabolic or plane reflectors, and so they have spread their radiations in all directions, frequently attaining success with remarkably low powers, for example, from England, to their antipodes in New Zealand with a quarter of a kilowatt, from Montreal to British Columbia, with 15 watts input and 5 watts output, and similarly from San Francisco to New Zealand. Best of all from Halifax to England with 2 watts!

Mr. J. Miller, of Montreal, signals to New Zealand with 100 watts and to England with anything from 30 to 110 watts.

He states that with the sun shining on his aerial he gets good results with 5-metre or 20-metre waves, but that the signals are poor in cloudy weather and fail entirely at night when he perforce lowers his frequency. There does not appear to be any known reason for this remarkable effect, which he states is a common enough experience. He states that 20-metre waves give him the best results by day. Miller states that with short waves, say 5 metres, there is frequently no reception within about 500 miles, but results are obtained at greater distances, as though the waves first mounted upwards and were then reflected or bent downwards.[1] Appleton makes similar statements.

Pittsburgh broadcasts both on 62 metres and on 309 metres,

[1] I learn that rays from Pittsburgh to Australia pass Fiji, but cannot be detected there. (See also the papers of Reinartz in *Q. S. T.*)

so that comparison can be readily made between these waves. The shorter wave (62 m.) conveys speech admirably at short distances, but the results are described as "mushy" at greater distances, at Montreal, for instance. Indeed some amateurs believe that the higher audio tones travel faster on the carrier wave than do the lower audio tones, a difficult matter to explain, if correct.

For transmission amateurs do not use the ground but a "counterpoise" or series of wires beneath the main aerial, the two sets being 60 and 20 feet above the ground for example. In other cases the aerial is vertical, ungrounded, with a coil in the middle coupled inductively or by capacitance with the transmission set. The skill and perseverance of amateurs is worthy of more recognition, and their results have great scientific interest.

ADVANCES IN THEORY.

The old question as to the method by which wireless waves travel round the earth has had much life given to it by a valuable discussion and theory due to Sir Joseph Larmor, published in the *Philosophical Magazine* for December, 1924.

Again, in the *Proceedings of the Physical Society of London* (February 15, 1925) there is a full summary of a joint meeting of the Physical Society of London and the Royal Meteorological Society. This summary should be read, because it throws much light on so many interesting and important topics. The speakers included Eccles, Chree, Appleton, C. T. R. Wilson, Simpson, Chapman and others.

A brief summary will be here given indicating the modern viewpoint.

In June, 1912, Eccles [2] first gave a theory of the Heaviside layer of ionized gas, highly conducting and supposed to be capable of reflecting electromagnetic waves in the higher atmosphere, while in the middle atmosphere the ionization is assumed to be sufficient to bend the rays round the earth. Eccles attributed the bending to the small oscillations given by the radio waves to molecular ions.

To-day Larmor assigns the bending to light ions, such as hydrogen ions, or to electrons, or to both.

Fifty miles (80 km.) up in the atmosphere the free path of

[2] *Proc. Roy. Soc.*, p. 86.

molecules between collisions is 2 cm., while the number of molecules per cm.^{3} is 10^{15}, as compared with 3×10^{19} near the earth.

Larmor shows that during the time when the light ions or electrons are moving quite unimpeded from one collision to the next, there is time for the wireless waves to set them into vibration with a not insignificant amplitude (which varies with the square of the wave-length). These oscillations constitute a current of a character quite similar to a Maxwellian displacement current. The true dielectric constant is decreased, and the velocity of the wireless wave is correspondingly increased.

Hence with correct adjustment of the transmitter the rays can be directed round the earth to distances such as 13,000 miles, travelling in their journey between the earth and the conducting layer about 50 miles above it. At the best an aerial can draw on this radiation over an area of the order of the square of the wave-length employed. There is sufficient energy for all receivers.

The dielectric constant, K, becomes the effective K' where

$$K' = K\left(1 - \frac{N^2 e \lambda^2}{\pi m}\right)$$

Here N is the number of electrons or light ions per cm.^{3}, e is the charge and m the mass of any one of them, while λ is as usual the wave-length.

Larmor shows that even *one* freely moving electron per cubic centimetre at the upper limit would suffice for the requisite bending round the earth, especially as he points out that free electrons can and do frequently pass through atoms without collision with the constituent parts of the atoms.

On the other hand, it appears that we must abandon the Heaviside layer as a reflector! Theory indicates that it would absorb and scatter and hence destroy wireless waves, rather than reflect them. Yet most practical radio experts find strong indications of reflected waves.[3]

Appleton suggests that the rays are bent rather than reflected by the Heaviside layer, so that we have a mirage rather than a reflector influence.

Chapman points out that he finds from magnetic results that the conductance of the upper layers is equivalent to a metre

[3] In a later letter to *Nature*, Larmor points out that with fairly abrupt transition to a well-ionized layer there may be reflection of wireless waves analogous to the reflection of light from metals.

thickness of copper over and around the earth. This layer is penetrated by short wave radiation such as light, but it would presumably not be penetrable by radio waves.

If radio waves go half round the earth with the velocity of light (c), then the upper part of the waves have a longer path to travel, and to keep up with the lower parts they must necessarily move faster than light. This at first appears disconcerting to the relativist! But the difficulty is capable of explanation.

ATMOSPHERICS.

C. E. P. Brooks has collected valuable statistics on thunder-storms. A single station reports on an average 16 thunder-storms a year over an area of about 200 square miles, so that the whole earth has about sixteen million thunder-storms a year, or 44,000 a day. If on the average they last for an hour, then there are always 1800 thunder-storms in being, and allowing 200 flashes per hour per thunder-storm, we find 360,000 flashes an hour, or 100 flashes a second over the whole earth.

These will be sufficiently numerous then to disturb the most enthusiastic radio fan! For example, around London for a radius of 1000 km. there will be about one flash a minute in winter and about a dozen a minute in summer.

South Africa and South America appear to be the places where the greatest number of thunder-storms occur.

It seems quite certain that lightning flashes do cause atmospherics, but other causes may exist. For example, C. T. R. Wilson points out that there may be silent but abrupt discharges between the Heaviside layer and the upper regions of a thunder-cloud.

Appleton and others have taken observations on atmospherics with the Western Electric cathode-ray oscillograph. The disturbances are of four types indicated by Figs. 1–4.

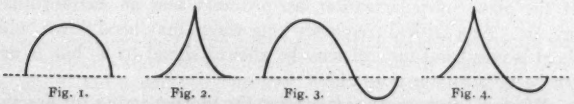

Fig. 1. Fig. 2. Fig. 3. Fig. 4.

The periods of these oscillations are measurable in millionths of a second, or microseconds (μs), and occasionally in thousandths of a second, or milliseconds (ms.). The electric forces

are not large, the main type being of the order of 1 volt for 8 metres, but at Khartoum as much as 250 volts has been received on the aerial, or 4.2 volts/metre.

An average lightning flash consists of from 3 to 6 discharges lasting each about 3 milliseconds with quiet intervals of a similar period intervening.

EXTINCTION OF SIGNALS.

Austen has accounted for the weakening of wireless waves with distance by an extinction factor $e^{\frac{-ar}{\sqrt{\lambda}}}$ involving the distance of propagation r, and (it will be noted) the square root of the wave-length. The constant a has a value of .28 for dry land or sand, and .0025 for water where r and λ are measured in kilometres. It is important to have a good conducting ground around the transmitting aerial so as to launch the radiation with an upright wave front.

Inasmuch as signals travel with less loss between flying aeroplanes than between ground stations, it appears that it may be desirable to launch waves tilted upwards from the ground.

ON WANDERING WAVES.

In addition to the Larmor bending effects due to light ions, it seems to have been proved that the earth's magnetic field, of the order of one-half a gauss, provided that ions or electrons are present, institutes a change of direction which will be least in the magnetic meridian and greatest for propagation at right angles to that direction.

Theory indicates that the plane of polarization may be rotated to an amount dependent on the electron density, the magnetic intensity and the frequency.

Hence we import into radio theory all the familiar peculiarities of double refracting crystals in physical optics, with rotation of the plane of polarization, an ordinary and an extraordinary ray, etc. At a critical frequency long waves may bend down, while short waves bend up. *A* may be able to signal to *B*, but *B* may not be able to signal to *A!*

We find here ample reasons for the violent errors in direction finding about the hour of sunset which are so troublesome in practice, and which were so obscure in theory. Nichols and Schelleng, of the Bell Telephone Company, have called attention to these

explanations in an article to *Nature;*[4] but much material had already been published in the *Physical Society of London Report* (February 15, 1925).[5]

It is interesting to find the theories of atmospheric electricity, earth's magnetism, and wireless waves all intermingled so that an advance in any one of them is likely to throw light on the other two, and this fact suggests the desirability of bringing atmospheric electricity within the scope of the meteorological offices of all nations.

In conclusion, I point out with delight the truly international and coöperative character of the brotherhood of radio investigators. When this spirit pervades further the people, the politicians and the governments of the nations of the world, we may begin to think and work internationally, and so bring about an age of thoughtful adjustment of difficulties instead of blind prejudice leading to hatred, war, waste and the possible destruction of such civilization as man has so far managed to achieve.

The Highest Aerial Tramway. (*Engineering World,* Aug., 1925, p. 104.)—The highest aerial tramway in the world, having a total length of more than five miles, is in use by the Caracoles Tin Company, Bolivia, for transporting ore from the workings to the mill. The mine is located on the upper eastern slope of the Andes Mountains near the headwaters of the Amazon River, at an altitude varying from 15,000 to 17,000 feet above sea-level, while the mill is in the valley below, at an altitude of between 11,000 and 12,000 feet.

Due to the prohibitive expense of road building, it was decided to build an aerial tramway which would follow a more or less direct line from the mine to the mill, a practice adopted by many mining companies where road transportation is not feasible. The tramway started operating approximately a year ago. On its way from the mine to the mill it crosses mountains and valleys, the greatest altitude reached being approximately 16,000 feet.

Two cables, suspended from steel towers, are used; one stationary over which the buckets move, and the other moving, for controlling the movement of the buckets. The tramway is broken up into two sections, both operated from a transfer station located where the two meet. Buckets travel at intervals of approximately 1000 feet apart and are moved down, after starting, by the weight of the ore which they contain. Empties are returned on the same continuous cable.

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[4] March 7, 1925, pp. 334–335.

[5] They give a clear and forceful statement (pp. 215–234) in the *Bell System Tech. Jour.* for April, 1925.

The cableway is controlled from the transfer station. General Electric equipment is used for this purpose, a 35-hp., 900 r.p.m., slip-ring, back-geared induction motor being utilized for starting. After starting, the motor floats on the line and acts as a brake on the regenerative braking principle, to prevent excessive speeds. A solenoid load brake is also used for emergency stopping.

The cableway is also utilized for transporting supplies from the mill to the mine, when the motor is called upon to furnish power for the drive.

The mine itself is not electrified, the veins being too small to allow room for such equipment, although electric lights are used in some of the main tunnels. Motor-driven air-compressors supply the compressed air for drills in the mine and the prime movers which furnish power to the mill and mine are hydro-electric. The air-compressor motors and the generating equipment are all of General Electric manufacture, with the exception of one French generator.

R.

Tin Mining in Malaya in 1924. (*Eng. and Mining Jour. Press*, Aug. 22, 1925, p. 308.)—A survey of mining in Malaya during 1924 indicates an unusual prosperity for the tin industry as a whole throughout the period. The labor employed in mining tin and tungsten at the end of 1924 was 106,479, not including labor employed on cutting and transporting firewood. The total exports of refined tin from British Malaya during 1924 amounted to 80,674 long tons. The United States took 46,194 tons of the year's exports and Great Britain took 16,334 tons, the shipments to that country having increased steadily during recent years. About 70 per cent. is reshipped to United States. R.

Aluminate Cement Now Made in America. (*Compressed Air Mag.*, Aug., 1925, p. 1347.)—While aluminate cement has been used extensively in France for more than a decade, still this valuable fast-setting structural material is only now being manufactured in America. The cost of this admirable product is somewhat higher than ordinary grades of cement owing to the amount of alunite employed in its making. But this added cost is more than offset by the very desirable properties of aluminate cement, which sets quickly and becomes as strong in the course of twenty-four hours as other cements do only after the expiration of twenty-eight days. R.

On the Use of Monochromatic X-rays in the Production of Laue Diagrams, and on the Structure of Mother-of-pearl. J. H. SHAXBY. (*Phil. Mag.*, June, 1925.)—By interpreting the spots formed on a photographic plate by X-rays that have passed through mother-of-pearl it was found that this substance consists mineralogically of "aragonite whose quasi-hexagonal axes are perpendicular to the planes of lamination." G. F. S.

STUDIES IN PHOTOGRAPHIC SENSITIVITY.*

VII. THE ACTION OF HYDROGEN PEROXIDE ON SINGLE-LAYER SILVER HALIDE PLATES.

BY

E. P. WIGHTMAN, A. P. H. TRIVELLI and S. E. SHEPPARD.

INTRODUCTION.

No work, with the exception of a few experiments of Svedberg [1] in 1920, has been published on the action of hydrogen peroxide on single-layer plates. The work which two of us [2] published previously dealt with the action of hydrogen peroxide on ordinary multi-grain-layer plates. At that time we proposed a tentative hypothesis of the mechanism of this action. Since then W. Clark [3] has discussed the work of ourselves and others, and has proposed an hypothesis based on the work of Fajans and Frankenburger,[4] and also, more recently, on some experiments of his own.[5]

He takes issue with our hypothesis that the action of hydrogen peroxide is primarily due to chemiluminescence. He thinks that the fogging action is purely chemical, and reversal due to a peptizing effect on the latent image with long exposures.[6] This involves the primary hypothesis that the "sensitivity specks" consist of some compound other than silver halide, probably silver oxide or hydroxide. Clark apparently considers that the actions of hydrogen peroxide and of sodium arsenite are entirely similar. This seems to us hardly likely in view of the results of recent experiments by ourselves with sodium arsenite,[7] and with hydrogen peroxide to be described below.

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* Communicated by Dr. C. E. K. Mees, Director of Laboratory and Associate Editor of this JOURNAL, and published as Communication No. 229 from the Research Laboratory of the Eastman Kodak Company. Presented in abstract at the Am. Chem. Soc. meeting, Baltimore, April, 1925.

[1] T. SVEDBERG: *Zeit. wiss. Phot.*, **20**, 36 (1920).

[2] S. E. SHEPPARD and E. P. WIGHTMAN: JOUR. FRANK. INST., **195**, 337 (1923).

[3] W. CLARK: *Brit. J. Phot.*, **70**, 763 (1923).

[4] K. FAJANS and W. FRANKENBURGER: *Z. Elektrochem.*, **28**, 499 (1922); *Z. physik. Chem.*, **105**, 255, 273, 329 (1923).

[5] W. CLARK: *Phot. J.*, **64**, 363 (1924).

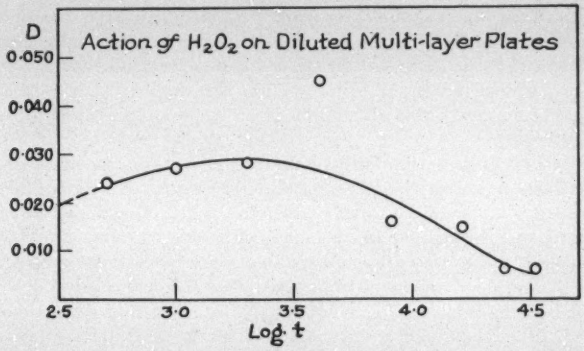
[6] This word is here used to mean "time of treatment."

[7] SHEPPARD, WIGHTMAN, TRIVELLI: JOUR. FRANK. INST., **198**, 629 (1924).

We have presented considerable evidence that the action of arsenite is on the silver halide. There is formed some kind of complex silver salt which itself is not very stable but decomposes slowly, precipitating silver, probably on the sensitive nuclei (though not necessarily so).[7a] This increases the size of the nuclei sufficiently to make the silver halide grain developable.

Although we disagree with Clark as to the mechanism of the action of arsenite, we do consider that it is purely chemical.[8] But we doubt whether the action of hydrogen peroxide is also a purely chemical one. The present work, while it does not conclusively confirm the hypothesis of chemiluminescence, is not incompatible

FIG. 1.



with it, moreover it furnishes fairly conclusive evidence that the theory of chemical action, particularly Clark's picture of this, is inadequate.

Before taking up the work on single-grain-layer plates we shall report some further work on ordinary plates.

[7a] In a still more recent paper (*Brit. J. Phot.*, **72**, 155 (1925)) Clark has again reiterated his claim that the bromide and monoarsenite do not react and has claimed further that the arsenite peptized silver bromide because a solution of it in contact with the bromide shows the Tyndall phenomenon. But colloidal silver resulting from decomposition of a complex silver arsenite would show the same phenomenon. We do not deny that a slight peptization of the HgBr may also occur.

[8] The possibility that autoxidation and chemiluminescence were concerned has been tested so far with negative results. Experiments are in progress to test this further, using copper salts to catalyze the oxidation of the arsenite.

H-ION CONCENTRATION AND THE ACTION OF H_2O_2.

Clark has argued that since hydrogen peroxide is more rapidly decomposed in alkaline than in acid solution, and since the production of latent fog on the photographic plate is greater in the latter than in the former, our theory is therefore untenable.

We admit the strength of this argument, and we have repeated the experiments more carefully, but with a different brand of plate, and another lot of hydrogen peroxide. The results are shown in Table I.

These results are in substantial agreement with those previously obtained, but show even less change of density with

TABLE I.

Effect of Acidity or Alkalinity on the Action of H_2O_2 on the Photographic Plate.

Approximate pH.	Average Density.	Conditions of Treatment and Development.
1.2	1.15	Time of treatment ..... 1 minute
2.4	0.87	Concentration of H_2O_2 ..... 0.2 M.
3.6	0.74	Temperature of all solutions ..... 20°
5.0	0.69	Thoroughly washed, running water .... ½ hour
6.2	0.77	Developed ..... 1:1 Pyro
7.0	0.80	Time of development ..... 3 minutes
8.2	0.79	Fixed ..... acid hypo
9.8	0.72	Washed and dried.
14.0	0.68	

change of pH value over a wide range of the latter. It is likely that the variations at the extremes of pH value are due to other causes than the greater or less acidity or alkalinity of the H_2O_2.

REMOVAL OF H_2O_2 BEFORE DEVELOPMENT.

The possibility occurred to us that the effect of the H_2O_2 was due to H_2O_2 adsorbed by the sensitive material giving chemiluminescence when brought in contact with developer. To test this, some plates after treatment with H_2O_2 were bathed in a 0.5 per cent. sodium sulphite solution for 10 minutes and were then washed in running water for 15 minutes. This insured the removal of H_2O_2 before developing, and hence the possibility of a chemiluminescent reaction with the developer—though not with the sulphite. The densities obtained for different times of treatment were practically identical with those for the H_2O_2 treatments not followed by sulphite. We may therefore conclude that the reaction of H_2O_2 with developer plays no part.

EFFECT OF H_2O_2 ON ONE-GRAIN-LAYER PLATES.

The first time we treated one-grain-layer plates with H_2O_2 we were very much surprised that there was no apparent effect. A very large number of experiments has since been carried out, with several kinds of one-grain-layer plates and numerous variations of the treatment, and in no case have we been able to affect more than about 10 per cent. of the grains. It should be said, that in every case tried the development fog was less than 2 per cent. and in most cases was practically *nil*.

In cases where the grains were not coated in a single layer, but in two or three layers, and in considerably greater numbers, a much more pronounced effect could be obtained with the H_2O_2.

The method of treatment of the plates was as follows: Single-layer plates, 5×12.7 cm.^{2}, were dipped (one-half their length) into the H_2O_2 of various concentrations from 0.003 M. to 10.2 M. (*i.e.*, about 0.01 to 30 per cent.) for times ranging from about 1 to 150,000 seconds, increasing as the power of 2. They were then washed for 10 minutes in running water and developed, some for 1 minute and others for longer times up to 10 minutes in the following developer at 17°:

p-amidophenol	7.278 g.
Na_2CO_3 (anhyd.)	50.00 g.
Na_2SO_3 (anhyd.)	50.00 g.
KBr	4.76 g.
H_2O to make	1000 c.c.

After development the plates were dipped in 1 per cent. acetic acid and then washed and dried.

In one case, a pyrogallol developer was used in comparison with the above in order to be sure that the lack of developability was not a question of kind of developer used. No greater effect was produced with this than with the p-amidophenol developer.

We summarize in Table II the results of these numerous experiments.

In addition to the variation of the concentration of H_2O_2, of the time of treatment with H_2O_2, and of the time of development, we likewise tried varying the character of the gelatin with which the original emulsion was diluted, and the type of emulsion

used. The results are given in the tables.[9] In one case ordinary multi-grain-layer plates were overcoated, some with ordinary gelatin and others with ash-free gelatin. When these were treated with H_2O_2 and developed, there was no difference in the densities of the fog produced, also overcoating single-layer plates with gelatin produced no greater effect than that on plates without the overcoating.

In preparing most of the single-layer plates the original emulsion was diluted with ash-free gelatin. In order to see if this had changed the characteristics of the grains with regard to H_2O_2 treatment, we coated one set of plates with emulsion diluted with ordinary gelatin. The results in this case were no different than with the plates prepared with ash-free gelatin.

The concentration of H_2O_2 was determined by Kingzetti's method.[10] In most of the experiments ordinary 3 per cent. U.S.P. product, or some dilution of it, was used. It was thought desirable, however, to try a more concentrated solution as well as one without preservative. Therefore experiments were carried out with various concentrations of Merck's "Superoxol," up to 30 per cent. These solutions were no more effective than the U.S.P. H_2O_2 in producing developability on single-layer plates, although the ease of reduction of "Superoxol" was very considerably greater.

As a check on the activity of the H_2O_2, ordinary plates of the same emulsion from which the single-layer plates were coated, were also treated with some of the same H_2O_2 for increasing times. They gave the usual density series. Further, as a check on the sensitivity of the single-layer plates, one of these (Eastman 40 emulsion) was exposed to light behind an Eder-Hecht step wedge in comparison with an ordinary plate of the same emulsion exposed in a similar way. The amount of light necessary to produce an equal number of visible density steps on each plate was about 1000 times more for the former (single-layer plate) than for the latter.

[9] It should be noted that the times of treatment of Lantern Slide and Eastman 33 were rather short as compared with those which produced an appreciable effect on Eastman 40. The former two were treated before it was found that such long times were necessary to produce any effect at all on the latter. But the effect at best is so small that it was thought of no great value to give further treatment on these other emulsions.

[10] TREADWELL-HALL: "Quantitative Analysis," Vol. II, p. 680.

TABLE II.

Action of H_2O_2 on Single-layer Plates.

Type of Emulsion.*	Concentration of H_2O_2.	Time of Treatment.	Time of Development.	Effect.
Eastman 40.....	0.00001 M.	10 seconds	60 seconds	No grains affected.
Eastman 40.....	0.003 M.	5 seconds	60 seconds	No grains affected.
Eastman 40.....	0.003 M.	60 seconds	60 seconds	
Eastman 40.....	0.03 M.	5 seconds	60 seconds	No grains affected.
Eastman 40.....	0.03 M.	60 seconds	60 seconds	
Eastman 40.....	0.3 M.	1 second	60 seconds	No grains affected.
Eastman 40.....	0.3 M.	5 seconds	60 seconds	
Eastman 40.....	0.3 M.	10 seconds	60 seconds	
Eastman 40.....	0.3 M.	100 seconds	60 seconds	
Eastman 40.....	0.6 M.	300 seconds	60 seconds	Less than 1 per cent. affected.
Eastman 40.....	0.6 M.	1200 seconds	60 seconds	Less than 2 per cent. affected.
Eastman 40.....	0.6 M.	20 seconds†	60 seconds	No grains affected.
Eastman 40.....	0.6 M.	3600 seconds†	120 seconds	Less than 5 per cent. affected.
Eastman 40.....	0.6 M.	5 seconds‡	240 seconds	Practically no grains affected, fog excepted.
Eastman 40.....	0.6 M.	20 seconds‡	240 seconds	
Eastman 40.....	0.3§ M.	10 seconds	60 seconds	No grains affected.
Eastman 40.....	0.3§ M.	40 seconds	120 seconds	
Eastman 40‖.....	0.3 M.	10 seconds	60 seconds	No grains affected.
Eastman 40‖.....	0.3 M.	60 seconds	60 seconds	
Eastman 40.....	0.03 M.	1 hour	3 series— 1 minute, 5 minutes, and 10 minutes each.	Practically no grains in 1 hour, less than 2 per cent. up to 4 hours with 5 and 10 minutes' development, and for remainder of treatments less than 5 per cent. developed in 1 minute, and less than 10 per cent. in 5 and 10 minutes, exclusive of fog.
Eastman 40.....	0.03 M.	2 hours		
Eastman 40.....	0.03 M.	4 hours		
Eastman 40.....	0.03 M.	8 hours		
Eastman 40.....	0.03 M.	16 hours		
Eastman 40.....	0.03 M.	32 hours		

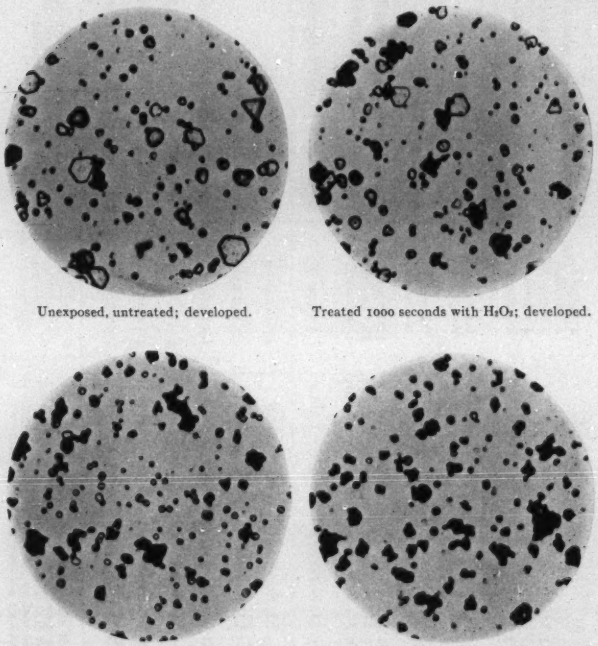
Eastman 40 ¶	0.3 M.	20 seconds	4 minutes	Densities both alike, about 0.5.
Eastman 40 **	0.3 M.	20 seconds	4 minutes	
Eastman 40 ††	0.3 M.	20 seconds	4 minutes	Density only slightly higher than preceding.
Eastman 40 ¶	0.3 M.	80 seconds	4 minutes	Densities both alike, about 0.9.
Eastman 40 **	0.3 M.	80 seconds	4 minutes	
Eastman 40 ††	0.3 M.	80 seconds	4 minutes	Density only slightly higher.
Lantern Slide ‡‡	0.3 M.	5 seconds	60 seconds	No grains affected.
Lantern Slide	0.3 M.	40 seconds	60 seconds	
Eastman 33 ‡‡	0.3 M.	5 seconds	60 seconds	No grains affected.
Eastman 33	0.3 M.	40 seconds	60 seconds	
Eastman Universal	0.1 M.	1 to 42 hours	120 seconds	Practically no grain affected.
Eastman Universal	9 M. Superoxol	1 second to 20 hours	180 seconds	Practically no grain affected.
Eastman Universal	0.9 M. Superoxol	1 second to 20 hours	180 seconds	
Eastman Universal multi-grain layer	0.9 M. Superoxol	1 second to 1 hour	4 minutes	Usual series of increasing densities.
Agfa Special (single layer)	0.3 M. Superoxol	1 second	4.5 minutes	No grains affected.
Agfa Special (single layer)	0.3 M. Superoxol	10 seconds	4.5 minutes	No grains affected.
Agfa Special (single layer)	0.3 M. Superoxol	100 seconds	4.5 minutes	Less than 1 per cent. affected.
Agfa Special (single layer)	0.3 M. Superoxol	1,000 seconds	4.5 minutes	Less than 5 per cent. affected.
Afga Special (single layer)	0.3 M. Superoxol	10,000 seconds	4.5 minutes	Less than 10 per cent. affected.
Agfa Special (single layer)	0.3 M. Superoxol	54,000 seconds	4.5 minutes	Less than 5 per cent. affected.

* These are single-layer plates unless otherwise specified.
† Unwashed after treatment, developed without drying.
‡ Rinsed with distilled H_2O after treatment.
§ H_2O_2 solution diluted with 15 per cent. EtOH by volume.
‖ Plates overcoated with a 1 per cent. gelatin solution.

¶ Multi-grain-layer plates overcoated with ordinary gelatin.
** Multi-grain-layer plates overcoated with ash-free gelatin.
†† Multi-grain-layer plates with no overcoating.
‡‡ See footnote 9, page 339.

The consideration of why a so much greater amount of light is necessary for one-grain-layer plates would be out of place here, but the fact is of interest in giving us a possible measure of what to expect in the case of H_2O_2. If 1000 times more light is necessary, then it would not be unreasonable to expect that 1000

FIG. 2.



Unexposed, untreated; developed. Treated 1000 seconds with H_2O_2; developed.

Exposed to light 161.4 M.C.S.; developed. Exposed to light 161.4 M.C.S. Treated 1000 seconds with H_2O_2; developed.

Effect of H_2O_2, of light, and of a combination of the two on single-layer plates.

times more H_2O_2 (either in time or concentration or both) would also be necessary for the single-layer plates. This ratio is apparently not maintained for the latter but is considerably greater. We know, for instance, from previous work [11] that the amount

[11] SHEPPARD and WIGHTMAN: JOUR. FRANK. INST., 195, 342 (1923).

of H_2O_2 necessary to produce the least perceptible image on an ordinary Graflex plate was 0.0063 mols/litre acting for 1 minute. On the other hand, it is seen from Table II above that 0.6 mols/litre acting for 5 minutes on an Eastman 40 single-layer plate affects less than 1 per cent. of the grains, which effect is not visible to the eye. If we assume for the moment that a reciprocity law holds, then this action is equivalent to 3 mols/litre for 1 minute, or 5000 times that for the ordinary Graflex plate. To produce the least *visible* image would require considerably more than this.

Since the reversing action of H_2O_2, as shown by previous results on ordinary plates, is more pronounced than that of light, it is possible that for single-layer plates, the reversing action practically counteracts the action producing developability.

This seems to be borne out by some further experiments which will now be described.

EFFECT OF H_2O_2 ON DILUTED MULTI-GRAIN-LAYER PLATES.

Plates were prepared by diluting the emulsion of an ordinary Eastman 40 plate to about four or five times the concentration usually used for coating one-grain-layer plates. Not only was the number of grains per cm.^{2} of the coated plate greater by this amount, but they were about three or four layers deep. When a series of these was treated for increasing lengths of time with H_2O_2 and developed, there resulted a series of densities as shown in Table III. These were measured by means of the thalophide-cell densitometer. The figures given are averaged from five plates. The densities were not large, to be sure, but were easily visible except for the longest times of treatment.

TABLE III.

*Thalophide-cell Density Measurements of Plates Treated with 0.3 M. H_2O_2.**

Time of Treatment in Seconds.	Average Density.
512	0.024
1,024	0.027
2,048	0.028
4,096	0.045
8,192	0.016
16,384	0.015
24,576	0.006
32,768	0.006

* Made for us by Mr. Schoen.

Shorter treatments than 512 seconds were not carried out, although it is evident that some effect would very likely have been produced for at least a couple of steps lower. The densities pass through a definite maximum. With very long times of treatment almost complete reversal is produced.

EFFECT OF PRE-EXPOSURE TO LIGHT.

We turn now to the most interesting phase of this work. On looking over again the work of Svedberg [12] with H_2O_2 on single-layer plates, it was noticed that about 14 per cent. of the smaller grains were affected by the H_2O_2, and about 35 per cent. of the larger ones, but that fog not due to H_2O_2 was of about the same order. We pointed out previously [13] that this fog was probably not due to a chemical effect, but to excessive exposure to the red light in the darkroom.

This led us to wonder if this pre-exposure to light had anything to do with the larger effect of H_2O_2 which Svedberg obtained and which we have not been able to repeat, when taking proper precautions to eliminate fog. Our results of H_2O_2 treatment of Agfa Special plates are seen from Table II above to agree with those on other plates, namely, not greater than 10 per cent. of all the grains were affected, no matter what the time of treatment. Moreover, contrary to Svedberg's observations, the action of the H_2O_2 on Agfa Special emulsion (Figs. 2 and 3) appears to be much stronger on the medium and small-size grains, whereas light on the average affects the large grains first. This will be tested quantitatively.

Some Agfa Special single-layer plates were given exposures to light on broad steps increasing as the power of 2. One-half the plate cut lengthwise was then dipped in 0.3 M. H_2O_2 for 1000 seconds at 20°. Additional plates were exposed in the same way and treated with distilled water for 1000 seconds. After washing both of these in running water, they were then developed in p-amidophenol for 4.5 minutes. Development was stopped with acetic acid in the usual way and the plates were washed and dried.

Photomicrographs were made from each step of both the blank unexposed plate, of the blank-light exposed, of the light-H_2O_2 exposed, and of the H_2O_2 exposed plates; also from the

[12] *Loc. cit.*

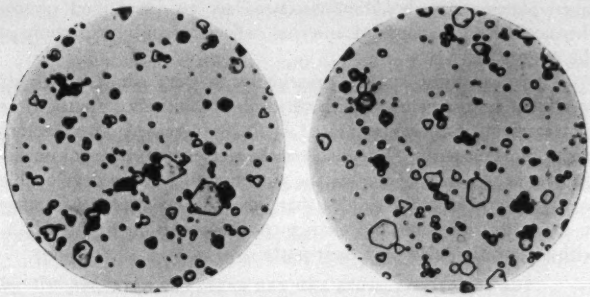
[13] WIGHTMAN, TRIVELLI, SHEPPARD: *J. Phys. Chem.*, 27, 1 (1923).

half of the plates above the light-H_2O_2 treatment, but the results here were practically no different than for the blank-light exposed.

Fig. 2 shows apparently how much more effective light plus H_2O_2 treatment is than either light or H_2O_2 treatment alone. Qualitatively, one would say that it is greater than the sum of the separate light and H_2O_2 treatments. Quantitative measurements are now in process to test this more accurately. At any rate, this qualitative observation appears to bear out our surmise with regard to Svedberg's work that the greater apparent effect of H_2O_2 in his case was due to previous light exposure.

We suggest the following hypothesis as to what causes this increased effect. The light not only produces a developable latent

FIG. 3.



Treated 10,000 seconds with H_2O_2; developed. Treated 54,000 seconds with H_2O_2; developed. Effect of long treatment of single-layer plates with H_2O_2.

image, but also an undevelopable one for the developer used, in other words, some of the sensitivity spots are raised almost, but not quite, to the developable state. The H_2O_2 not only carries these over, but creates its own proportion of developability as well from other sensitivity spots. This effect is made all the stronger by the fact that the greatest action of the H_2O_2 appears to be on the smaller grains while that of the light is on the larger ones. It is possible, of course, that other things than light may be able to produce this effect.

WHY IS ACTION OF H_2O_2 SO SLIGHT ON SINGLE-LAYER PLATES?

At first sight, one would expect to find that H_2O_2 would produce a greater effect on single-layer plates than on multi-layer plates, since there is greater freedom for action. Certainly, the

first action of H_2O_2 on multi-layer plates is only on the surface, since a 0.3 M. solution acting for only one second will produce a moderate fog. Now we might consider the single-layer plate as simply this top layer segregated on a plate by itself. Why should it then differ from its condition when other layers are under it? There appears no obvious answer to this question. Two possibilities, however, suggest themselves, in explanation of lowered sensitivity of the single-layer plates to peroxide and to light.

First, clumping is at a minimum in the single-layer plate, so that a smaller percentage of the total number of individual grains is affected than in the multi-layer plate. Secondly, there is the possibility that in the clumps of grains existing in the multi-layer plates, any chemiluminescence has an intensified photochemical effect because of internal reflection and irradiation in the aggregate.

This reasoning applies principally to very short times of treatment or to treatment with very dilute solutions. As the time of treatment or concentration of H_2O_2 is increased other factors play important parts. For instance the tendency to reversal, whatever its cause, may overcome the tendency to become developable to a greater extent in single- than in multi-layer plates because in the latter diffusion and change of concentration of the H_2O_2 with penetration also play their parts.

THE SENSITIVITY SPOTS AND THE CAUSES OF REVERSAL.

Clark claims that the cause of the reversal is due to increase of dispersity by the H_2O_2 of silver formed from the sensitivity specks [14] (which he considers consist of Ag_2O or AgOH [15]). It is true that when H_2O_2 is decomposed by Ag_2O, which is probably first oxidized to a peroxide, there results a colloidal solution of a mixture of silver and Ag_2O, the peroxide being unstable in water. We have shown this by adding H_2O_2 to pure solid Ag_2O. The decomposition of the H_2O_2 is quite violent, O_2 being freed very rapidly, and a reddish-brown colloidal solution results, which precipitates when excess H_2O_2 is added, but even in this condition is very active in reducing the H_2O_2.

It is also true that if the so-called sensitivity spots consisted of Ag_2O, then by treating the plate with a sufficiently dilute solu-

[14] W. CLARK: *Phot. Jour.*, **64**, 364 (1924).
[15] W. CLARK: *British J. Phot.*, **70**, 763 (1923).

tion of the H_2O_2 the Ag_2O would be reduced to Ag, but there would not be sufficient H_2O_2 in excess to peptize this and hence every grain with a sensitivity spot (provided it is large enough) would become developable, whether in multi-layers or in a single layer. That this is not the case for the latter has already been demonstrated above. Besides, after all the Ag_2O is once reduced, there would be no further growth of the resulting silver particle. The size of the Ag_2O spot would therefore have to be large enough to produce a developable centre of Ag, and reversibility then depends, as Clark states, entirely upon the peptizing of this by excess H_2O_2. If the sensitivity specks consisted of Ag_2O—or $\overset{+}{Ag}\,\overset{-}{OH}$—there appears no reason why they should not be reduced by a developer as easily as by hydrogen peroxide. Hence we should have spontaneous developability of both multi-layer and single-layer plates.

It is possible that alkaline and neutral pure H_2O_2 peptize colloidal silver, but tests which we have made with ordinary U.S.P. 3 per cent. H_2O_2, which has a pH of about 3.3, *i.e.*, is moderately acid, shows that it coagulates and precipitates colloidal silver, and it is this kind of H_2O_2 which we have used in most of our experiments. On the other hand, peptization by strongly alkaline H_2O_2 might explain why this solution produces less effect on ordinary plates than acid or neutral H_2O_2.

It is seen, therefore, that Clark's hypotheses are not supported by the facts.

On the other hand, if we re-examine the above results from the standpoint of the chemiluminescence theory, we see in the first place that in the beginning the chemiluminescence should produce developability in the same way as ordinary light, and excess of it may cause reversal in the same way as light. But we have still to explain why the single-layer plate is so little affected. In addition to the possible explanations already given for the much lower sensitivity to light of the single-layer plate as compared with that of the multi-layer plate, which would apply also for H_2O_2 treatment, it may be simply a question of total number of grains. If there were the same proportion of developable grains in the two cases, the plate with twenty times the number of grains on it as compared with the other would show a fairly high density for the maximum effect.

We propose to test this hypothesis by treating an ordinary

plate with H_2O_2 and developing it, but not fixing it. The emulsion with both developed and undeveloped grains will then be removed and coated in single layers and the proportion of affected grains determined. Some way of taking into account the clumping will also have to be found.

In conclusion, it should be noted that Fuchs [16] has given some corroborative evidence on the similarity of the chemiluminescent action of developers undergoing oxidation by the air, and the action of hydrogen peroxide.

SUMMARY.

(1) Single-grain-layer silver halide plates are only very slightly affected by hydrogen peroxide, no matter what the concentration of H_2O_2 or time of treatment, unless they have been given a previous light exposure. In this case the number of grains showing developability seems to be greater than the sum of those produced by light and hydrogen peroxide separately.

(2) The reason suggested for this is that not only developable latent image, but also undevelopable image is produced by light and that the hydrogen peroxide carries this over into developable latent image as well as makes its own proportion of grains developable.

(3) It is shown that Clark's hypotheses (*a*) that the so-called sensitivity of specks consists of silver oxide or hydroxide, (*b*) that the action of hydrogen peroxide is a purely chemical one on this oxide or hydroxide, reducing this to silver, which then makes the plate developable, are untenable, not being supported by experimental facts, and (*c*) that reversal is due to peptization of the silver by the hydrogen peroxide, is still open to question.

(4) It is further shown that while our original hypothesis that the action of H_2O_2 is one of chemiluminescence is not completely substantiated, it is at least not strongly contraverted except by one fact, namely, that acid H_2O_2 seems to be slightly more effective than alkaline H_2O_2 in producing a latent image. On the other hand, alkaline H_2O_2 may cause peptization of the sensitivity specks and hence work against the formation of developable centres.

ACKNOWLEDGMENT.

We wish to thank Miss Bessie LaBar, Mr. F. G. Keenan and Mr. R. Quirk for assistance in the experimental work.

[16] E. FUCHS: *Phot. Ind.*, p. 27, Jan. 23, and p. 56, Feb. 6, 1924.

AN INVESTIGATION OF THE ALLEGED ALLOTROPY OF ZINC BY X-RAY ANALYSIS AND A REDETERMINATION OF THE ZINC LATTICE.*

BY

W. M. PEIRCE,† E. A. ANDERSON,‡ P. VAN DYCK.§

INTRODUCTION.

CLAIMS of the existence of two or more allotropic modifications of zinc have been resorted to by a number of writers in explanation of irregularities in the variation of certain properties of zinc with the temperature. In this way the impression has become more or less general that in all probability zinc exists in more than one allotropic form. This has frequently led us in this laboratory to consider an allotropic change as a possible explanation of observed facts for which we were prepared to offer no satisfactory explanation.

Certain isolated but carefully conducted experiments to detect allotropic changes have been performed in our laboratories at various times with only negative results. Moreover a very careful study of every available paper in which the author claims to have demonstrated an allotropic change has revealed in each case circumstances in the planning or execution of the experiments or in the interpretation of results which lead us to doubt the conclusions. That such circumstances have seriously influenced the accuracy of the findings is evident from the lack of consistency among the conclusions of various workers.

The X-ray method has provided us with a new and very direct means of seeking a definite answer to this problem.

According to the usual conception of allotropy, as affecting the structural condition of metals, atoms of the same kind are capable of arranging themselves in more than one space lattice, and each possible arrangement is stable in a definite range of

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temperature different from that at which any other arrangement is stable.

Such changes in the arrangement of the atoms are naturally more or less strongly reflected in changes of physical, mechanical, chemical and electrical properties. Unfortunately, some or all of these changes are often of small magnitude and difficult to detect. Moreover, since they occur in solids in which movement of the atoms is considerably restricted (*i.e.*, the atomic mobility is low), these changes frequently take place very slowly. In some cases by rapid cooling to a point well below the transformation point the rate of change may be reduced nearly to zero.

Many of the properties, the variation of which may serve to indicate allotropic changes, cannot be readily measured at temperatures other than room temperature. It becomes necessary, therefore, to depend on quenching to retain at room temperature an allotropic form stable only in another temperature range.

The observation of changes in the properties mentioned, as a means of detecting allotropic transformations, is not only attended by the above difficulties, but there is the further complication that these properties may also be changed by variations in composition, mechanical treatment, the size of the crystals, their orientation, etc.

The X-ray, on the other hand, offers a direct method, largely free from these objections, since it measures directly the spacing and arrangement of the atoms. While the presence of other metals changes the distance between the atoms slightly, the change is negligible for very small amounts of impurities. Any change in the X-ray pattern due to cold working of the metal can be eliminated by preliminary annealing of the specimens used.

The X-ray method may be adapted to measurements of the atomic arrangement over a wide range of temperature and hence it is not necessary to depend upon quenching to preserve a possible allotropic form in a metastable condition at room temperature.

It follows from the direct nature of the X-ray method that negative results are conclusive, whereas in the case of indirect methods there is always the possibility that an allotropic change is occurring without appreciably affecting the property under investigation.

We have, therefore, carried out the present study of the space

lattice of zinc at temperatures from room temperature to 400° C. to determine whether or not a change occurs in this range.

In the course of our work we necessarily carried out a series of precise determinations of the zinc lattice on specimens of zinc which were virtually spectroscopically pure. We believe that these results in themselves are of value in confirming previous determinations.

Dr. C. H. Mathewson has kindly permitted us to include results of work done by Mr. Albert J. Phillips at Yale University, in which the axial ratio has been crystallographically determined on crystals of zinc of the same purity as that which we employed. These results serve to remove the most serious discrepancy existing in previous work on the zinc lattice, namely, the difference between the axial ratio as determined crystallographically and as determined from X-ray spectrograms.

REVIEW OF PREVIOUS WORK.

For the reasons set forth in the introduction, the writers believe that conclusions as to the allotropy of zinc, based on X-ray crystal analyses of pure annealed zinc, extending over the temperature range in question, can be disputed only on the basis of errors in the X-ray work or conflicting X-ray evidence.

We feel, therefore, that any attempt at explanation of the anomalies in the behavior of zinc which earlier investigators have reported, lies outside the province of this paper, and we shall not enter into a discussion of their work further than has been done in the introduction.

We have appended for reference, the three most recent papers on this subject. One of these authors, Losana, merits the distinction of being the only writer advancing evidence in support of an allotropic change in zinc who describes attempts to reverse the changes observed. Unfortunately, the zinc which he used was relatively impure.

Our problems in regard to the X-ray study of zinc were simplified by previous workers who have established the structure of zinc at room temperature.

A. W. Hull [4] made an analysis of the zinc lattice using powder reduced with hydrogen from the oxide at 600° C. His evidence indicated a hexagonal close-packed arrangement of prolate spheroids having an axial ratio of 1.860. The side of the elementary

zinc prism was found to be 2.670 Å.U. and the height 4.966 Å.U.

The nearest distance between atoms in the basal plane was 2.670 Å.U. and in the pyramid plane 2.920 Å.U.

R. W. G. Wyckoff [5] notes that the axial ratio 1.86 is not in agreement with the crystallographically determined ratio 1.356.

Mr. Albert J. Phillips * has recently completed some interesting measurements of the axial ratio of zinc crystals as part of a thesis for the degree of Master of Science at Yale University. Eight small crystals prepared in this laboratory by slow vacuum distillation were measured with the reflection goniometer. In every case the crystal habit was found to be the same, namely, the first order hexagonal prism cut by first order pyramids and truncated by basal pinacoids.

TABLE I.

Crystal.	Basal 0001.	Pyramid $10\bar{1}1$.	Prism $10\bar{1}0$.	Pyramid $10\bar{1}1$.
1	..	245°– 6′ (G)	270°– 5½′ (E)	295°– 8′ (G)
2	..	64 –21 (G)	89 –23½ (E)	114 –27½ (G)
3	..	..	79 –48	54 –31
4	26°–33′ (F)	321 –56½ (P)	296 –55 (F)	271 –25½ (P)
5	..	249 –15	273 –50	..
6	..	230 –17½	205 –01	179 –31
7	284–40 (P)	169 –39 (F)	194 –34½ (G)	219 –12½ (F)
8	293–48 (P)	227 –60 (F)	203 –16 (G)	178 –32½ (E)

E—excellent; G—good; F—fair; P—poor signal.

The zone measured was that starting with the basal pinacoid and extending down to the lower pyramid plane (*i.e.*, 0001 to $10\bar{1}1$ to $10\bar{1}0$ to $10\bar{1}\bar{1}$). The measurements shown in Table I were made on the eight crystals.

TABLE II.

Crystal.	Basal 0001.	Pyramid $10\bar{1}1$.	Prism $10\bar{1}0$.	Pyramid $10\bar{1}1$.
1	..	24°–59½′	0°–0′	25°– 2½′
2	..	25 – 2½	0	25 – 4
3	..	..	0	25 –14
4	89°–37′	25 – 6	0	25 –40
5	..	24 –35	0	..
6	..	25 –16½	0	25 –30
7	90 – 5½	24 –55	0	24 –38
8	90 –32	24 –44	0	24 –43½

* Private communication to the writers.

With the prism as a reference plane, the angles given in Table II were obtained from Table I.

The average of the angles obtained from "good" signals was found to be 24°–54′. This is the angle between the first order pyramid plane and the vertical axis.

On the basis of these figures, the axial ratio is found to lie between 1.86 and 1.87, which is in close agreement with Hull's value of 1.86 determined by X-ray analysis.

EXPERIMENTAL WORK.

Zinc Used.—The zinc used in all experiments was prepared by Mr. H. M. Cyr, of this laboratory, by vacuum redistillation of zinc 99.993 per cent. pure. Within the range 2450–3650 Å.U. only one impurity line, and that an extremely faint lead line, 2833 Å.U. could be found in the resulting product when it was examined in the carbon arc before a quartz spectrograph.*

X-ray Apparatus.—The work in this investigation was carried on with a General Electric Company X-ray Diffraction Apparatus. The spectrograms, taken on Eastman Kodak X-ray films, were obtained by the Hull or Debye-Scherrer method.

A Coolidge tube operating at 30,000 volts and 25 milliamperes produced the molybdenum alpha doublet ($\lambda = .7078$ Å.U. and .7121 Å.U.) used. The diffracted radiation was passed through a zirconium oxide filter, the portion striking the film being essentially monochromatic.

An instrument designed by the General Electric Company was used to measure the films obtained. The interplanar distances were used directly from the scale.

In order to avoid errors in the position of the zero line, the films were set on the scale by means of the 1.170 line, excepting in the case of the precision experiments where the 2.814 line of the NaCl pattern was used.

An Analysis of the Crystal Structure of Zinc.—In view of the great purity of the zinc on hand it was decided to determine as accurately as possible the atomic arrangement of zinc.

Four good films were obtained from two specimens, zinc

* It is interesting to note that Dr. C. H. Mathewson has found very pronounced differences in grain growth in this zinc and the 99.993 per cent. zinc from which it was distilled. Several investigators have based claims of allotropy on microstructural changes.

powder mixed with finely divided NaCl and zinc powder mixed with NaCl and flour. The zinc powder used was formed in the condenser during the vacuum distillation.

The specimens were contained in thin-walled glass tubes of less than .015 inch inside diameter. Since the NaCl and the zinc were intimately mixed the conditions present for one crystal

TABLE III.

Average Interplanar Distances Measured from Four Films of NaCl and Zinc.

NaCl Calculated.	NaCl Observed.	NaCl Intensities.*	Zinc Calculated.	Zinc Observed.	Zinc Intensities.*	Planar Indices.
2.814	2.815	7	2.474	2.474	2	0001 (2)
			2.301	2.301	1	$10\bar{1}0$
			2.086	2.090	8	$10\bar{1}1$
1.992	1.992	5				
			1.685	1.687	2	$10\bar{1}2$
1.624	1.625	2				
1.407	1.410	1				
			1.340	1.337	3½	$10\bar{1}3$
			1.328			$11\bar{2}0$
1.257	1.261	3				
			1.237	1.234	⅛	0001 (4)
			1.170	1.171	2	$11\bar{2}2$
1.148	1.148	†	1.151	1.148	†	$10\bar{1}0$ (2)
			1.121	1.122	1½	$20\bar{2}1$
			1.089	1.088	¼	$10\bar{1}4$
			1.043	1.044	⅛	$10\bar{1}1$ (2)
.994	.997	¼				
.940	.942	†	.944	.942	†	$20\bar{2}3$
			.909			$10\bar{1}5$
			.905	.906	½	$11\bar{2}4$
.889	.890	¼	.870			$21\bar{3}0$
			.857	.857	½	$21\bar{3}1$
			.842	.845	⅛	$10\bar{1}2$ (2)
			.825			0001 (6)
			.821			$21\bar{3}2$
			.776			$10\bar{1}6$
			.769	.770	¼	$21\bar{3}3$
			.767			$10\bar{1}0$ (3)
.752	.753	¼				
.732	.734	¼				

* Intensities on a scale from 10 heavy to ¼ very faint, and ⅛ exceedingly faint.
† Coincidence of lines from both crystals renders evaluation of intensities impossible.

affected the others, and it was possible to measure each pattern in the centre of the film.

The General Electric Company X-ray Diffraction Apparatus used employs one quadrant of film with the advantage that it is possible to set the film in the measuring scale by means of one line from the standard crystal, in this case NaCl. In the present work the 2.814 line was used to set the film on the scale. It was found unnecessary to use a correction curve for the readings

because the observed values for NaCl checked very closely with the calculated values.

In Table III are compiled the average values found from the four films. From the basal and prism plane reflections, second and first order, respectively, the following values were calculated:

$$a = 2.657,\ c = 4.948,\ c/a = 1.862.$$

This axial ratio checks that found by Hull. It will also be noted from Table IV that our interplanar distances check very closely with Hull's calculated and observed values.

TABLE IV.

Comparison between Hull's Calculated and Observed Interplanar Distances and Those Obtained in the Present Work.

Hull Calculated.	Hull Observed.	Intensity.	Author's Calculated.	Author's Observed.	Intensity.	Planar Indices.
2.466	2.472	3	2.474	2.474	2	0001 (2)
2.295	2.293	1	2.301	2.301	1	$10\bar{1}0$
2.080	2.077	10	2.086	2.090	8	$10\bar{1}1$
1.678	1.684	2	1.685	1.687	2	$10\bar{1}2$
1.337	1.339	10	1.340	1.337	3½	$10\bar{1}3$
1.326	1.332	10	1.328	—		$11\bar{2}0$
1.232	1.235	½	1.237	1.234	½	0001 (4)
1.166	1.172	7	1.170	1.171	2	$11\bar{2}2$
1.148	1.152	½	1.151	—		$10\bar{1}0$ (2)
1.119	1.121	4	1.121	1.122	1½	$20\bar{2}1$
1.087	1.088	½	1.089	1.088	¼	$10\bar{1}4$
1.041	1.044	1	1.043	1.044	½	$10\bar{1}1$ (2)
.948	.947	2	.944	—		$20\bar{2}3$
.913	.910	2	.909	.906	½	$10\bar{1}5$
.910			.905			$11\bar{2}4$
.874	—		.870	—		$21\bar{3}0$
.861	.859	3	.857	.857	½	$21\bar{3}1$
.845	—		.842	.845	½	$10\bar{1}2$ (2)
.828	.827	1	.825	—	—	0001 (6)
.825			.821			$21\bar{3}2$
.778	—		.776	—	—	$10\bar{1}6$
.773	.773	2	.769	.770	¼	$21\bar{3}3$
.771			.767			$10\bar{1}0$ (3)
.754	.756	1	—	—		$20\bar{2}5$
.736	.737	2	—	—		$30\bar{3}2$
.715	.717	¼	—	—		$21\bar{3}4$
.703	.703	½	—	—		$11\bar{2}6$

PRELIMINARY WORK ON MAKING DETERMINATIONS AT ELEVATED TEMPERATURES.

Considerable preliminary work was necessary before a suitable method could be devised to maintain a satisfactory specimen at the desired temperatures.

The use of zinc wire heated by the passage of a low voltage current was suggested as a convenient means of maintaining a desired temperature. Samples of wire, .005 inch in diameter, prepared from the pure zinc described above were enclosed in fine glass tubes and heated.

The orientation of the crystals in a drawn wire, however, is nearly uniform with respect to the axis of the wires, as others have reported and our work confirmed. The lack of a diversified orientation resulted in the failure of certain planes to "reflect" the X-ray beam. Rotation of the wire produced no appreciable increase in the number of lines noted in the patterns obtained, since the symmetry with the axis was not affected.

In an effort to produce a more diversified orientation than was provided by a drawn wire, samples of wire were rolled flat and twisted. While this twisted ribbon showed a more random orientation of planes than the drawn wire from which it was produced, the results were not entirely satisfactory. Certain planes failed to reflect, while several appeared in some of the films and not in others. The appearance or non-appearance of these lines was entirely fortuitous, varying in no consistent way with the temperature, and in no way indicated a change in atomic arrangement.

On films obtained over a range of temperatures from 20° C. to 375° C. over 50 per cent. of the lines calculated by Hull appeared. This alone indicates that no allotropic change took place, as it is difficult to imagine a change in atomic arrangement which would leave 50 per cent. of the spacings unchanged.

This preliminary work on ribbon and wire was reported by Dr. C. H. Mathewson in an address delivered at the Centennial of The Franklin Institute, September, 1924.*

In our precision measurements of the zinc lattice, zinc powder mixed with flour and contained in a glass tube was found to give satisfactory patterns. It was then necessary to devise a means of heating the powder to the required temperature.

In one experiment the powder specimen contained in a fine glass tube was placed in a larger tube, through which heated air was passed. Temperatures were measured by means of two

* Dr. C. H. MATHEWSON: "The Trend in Physical Metallurgy," JOUR. FRANK. INST., January, 1925.

copper-constantan thermocouples placed in the inner tube adjacent to the powder.

This method was not satisfactory because of the scattering of the X-ray beam by the double glass tube. This scattering resulted in a general darkening of the film, causing great difficulty in observing and measuring faint lines.

The final experiments were made by heating zinc powder mixed with flour, by direct radiation. The specimen, contained in a fine glass tube passing through asbestos plugs in the ends of a piece of brass tubing, was heated by radiation from resistance wires inside the tube (Fig. 1). Suitable slots cut in the brass tube allowed the X-ray beam to pass through the tube.

Temperatures were measured by means of a copper-constantan couple inserted in the fine inner tube adjacent to the zinc powder. This couple was carefully calibrated before and after the experiments. No difficulty was found in holding the temperature within a range of 20 degrees without resorting to a more careful means of temperature control. Had there been any indication of an allotropic change it would, of course, have been necessary to introduce this refinement in order to locate the transformation temperature accurately.

Temperatures Used.—In these final experiments we aimed to secure a set of X-ray spectrograms taken of the same specimen without disturbing its position in the apparatus, at a series of five temperatures between room temperature and the melting point. The specimen, as previously stated, was the powder portion of the distillate from vacuum distillation of C. P. zinc. After packing in the glass specimen tube, it was annealed for an hour somewhat above 300° C. and then cooled slowly in the furnace, ten hours being necessary for it to reach room temperature.

The first spectrogram was taken at 20° C., following which the temperature was raised successively to 115°, 200°, 295° and 400° C., and a spectrogram was made at each temperature. The last temperature, 400° C., we had previously found was as high as we could safely go without danger of melting some portion of the specimen at some time during the nine-hour exposure.

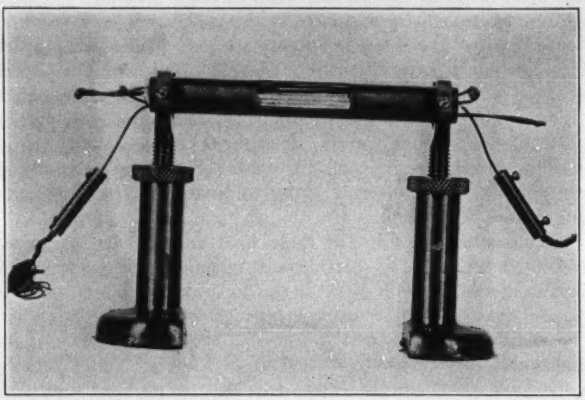
No preliminary heating at the successive temperatures was considered necessary to allow any possible transformation to occur since it is unusual for such a change to take place slowly in passing from a lower to a higher temperature. At the highest tempera-

ture particularly, 400° C., the close proximity to the melting point would lead us to expect that any change would take place with great rapidity.

Half-way through the exposure at 400° C. one of the heating wires failed, causing a material drop in temperature for the remaining half of the exposure. Unfortunately the specimen tube was damaged and the entire apparatus had to be removed from its position.

While this film showed neither any change in lattice as between this and lower temperatures, nor any confusion of the

FIG. 1.



lines due to the temperature change during the exposure, the precaution was taken of preparing a new specimen and making a spectrogram at 400° C.

The temperature was then dropped successively to 300°, 215°, 115° and 20° C., and spectrograms taken. The cooling between temperatures was fairly rapid perhaps in the order 15° or 20° per minute due to the small mass of the specimen and heating tube. Even this rate, however, should allow any changes to occur. Furthermore, when the nine-hour exposure at each temperature is considered, it is difficult to conceive of any transformation remaining suppressed when room temperature was reached.

DISCUSSION OF RESULTS.

The interplanar distances found from the spectrograms obtained in this work are compiled in Table V. At least ten lines from the calculated pattern appear on every film.

The line corresponding to an interplanar distance of 1.337 Å.U. is read at lower temperatures as a broad single line. At higher temperatures the two calculated lines (1.337 and 1.328 Å.U.) become visible due to the expansion of the space lattice.

In several cases lines which are very faint at room temperature become exceedingly faint or disappear at higher temperatures. This is probably caused by increased scattering of the X-ray beam by the glass-containing tube which has been observed to occur at the higher temperatures.

Another reasonable explanation lies in the increased amplitude of vibration of the atoms at elevated temperatures. This is the best explanation which has been offered for the failure of the sodium and potassium patterns to appear at room temperature, which is of course near their melting points.

The planar spacings, 2.301 and 2.086 Å.U., appear to decrease perceptibly with increasing temperatures. No sharp change occurs, however, at any definite temperature. These lines are, moreover, subject to the greatest error in measuring. The portion of the film on which these lines occur is subject to considerable heating by radiation from the heating device.

Two very faint lines (1.288 and 1.262 Å.U.), not in the calculated pattern, appear in certain of the patterns. There appears to be no direct relationship between the occurrence of these lines and the temperatures at which the patterns were obtained. Spectrograms taken through the heating device, containing no specimen, indicate that at least one of these lines is caused by some portion of the apparatus coming in contact with the X-ray beam. The occurrence of the lines, moreover, is entirely fortuitous and does not indicate in any way an allotropic change.

None of the variations noted above indicate more than mechanical difficulties, due to the temperatures used, there being no indication of a change in space lattice with temperature.

If a second allotropic form of zinc exists, it can not possess a wholly dissimilar atomic arrangement such as occurs in the case of iron.

TABLE V.

Interplanar Distances—Å.U.

20° C.		115° C.		200° C.		295° C.		400° C. ‖		400° C.		300° C.		215° C.		115° C.		20° C.		Calculated.	
Å.U.§	I.‡	Å.U.	I.	Å.U.	I.	Å.U.	I.	Å.U.	I.	Å.U.	I.	Å.U.	I.	Å.U.	I.	Å.U.	I.	Å.U.	I.	Å.U.	I.
2.475	4	2.465	3	2.475	2	2.472	1½	2.475	2	2.465	2	2.475	3	2.47	2	2.475	3	2.472	3	2.474	
2.305	1	2.298	1	2.295	½	2.285	1	2.275	1½	2.278	1	2.29	1	2.298	1	2.30	½	2.30	1	2.301	
2.092	10	2.082	9	2.078	7	2.076	7	2.075	8	2.072	7	2.08	7	2.082	7	2.092	7	2.09	7	2.086	
1.687	1½	1.683	1½	1.687	1	1.683	1½	1.687	1	1.680	1	1.686	1	1.685	1½	1.684	1	1.686	1½	1.687	
1.337	3	1.337	3	1.344	2	1.346	1½	1.344	1½	1.343	1½	1.344	1½	1.335	2	1.336	2	1.338	3	1.337	
				1.325	2	1.325	1	1.324	1½	1.323	1½	1.325	1½							1.328	
1.288	?†	.....		.....		1.279	?	.....		.....		.....		.....		1.292	?	1.288	?		
1.262	?	.....		1.255	?	1.255	?	1.250	?	.....		.....		.....		1.262	?	1.261	?		
1.238	*	.....		.....		.....		.....		.....		.....		.....		.....		1.238	*	1.237	
1.170	2	1.170	2	1.170	2	1.170	2	1.170	1½	1.170	1½	1.170	1½	1.170	2	1.170	2	1.170	2	1.170	
1.120	1½	1.121	2	1.121	1	1.120	1	1.120	1	1.120	1½	1.120	1½	1.120	2	1.120	1½	1.120	1	1.121	
1.090	¼	1.090	¼	.....		.....		.....		.....		.....		.....		1.090	*	1.089	*	1.089	
1.043	¼	.....	...	.....		.....		.....		.....		.....		.....		1.041	*	1.042	*	1.043	
.944	½	.945	½	.945	¼	.947	*	.....		.946	¼	.946	¼	.948	¼	.944	¼	.945	¼	.948	
.905	½	.906	½	.....		.....		.....		.....		.....		.....		.905	½	.905	½	.909	
																				.905	
.858	1	.860	1	.857	½	.855	¼	.860	¼	.857	½	.855	½	.859	¼	.856	1	.857	½	.857	
.852	¼	.852	¼	.851	¼	.....		.....		.....		.....		.....		.851	¼	.823	¼	.842	
.768	½	.772	¼	.768	¼	.....		.....		.....		.....		.771	¼	.770	¼	.770	¼	.769	
																				.767	
.732	1½	.734	¼	.731	¼	.730	¼	.730	1	.....		.....		.732	*	.....		.734	¼	.736	

* Exceedingly faint.
†? Not in a calculated pattern; exceedingly faint.
‡I. = Intensity; scale 10 for heavy to ¼ for very faint.
§ Å.U. = Ångström unit = 1×10^{-8} cm. = .0001μ.

‖ In this run one of the heating elements failed, thus lowering the temperature materially during the last half of the run and damaging the specimen tube so it could not be used again. The succeeding runs were made with another specimen.

CONCLUSIONS.

From the data obtained the following conclusions are drawn:

(1) Zinc occurs with a hexagonal, close-packed crystal structure, having an axial ratio 1.86. This is in close agreement with Hull's findings.

(2) Within the limits of experimental error, there is no change in the X-ray diffraction pattern of pure zinc at atmospheric pressure and between 20° and 400° C., indicating that within this temperature range zinc occurs in only one form, there being no allotropic transformation in this range.

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Swiss Cable-incline Railway. (*Engineering News-Record*, Aug. 20, 1925, p. 313.)—A steep-grade cable-incline railway 2300 feet long, with grades of 53 and 73 per cent., opened in 1924, affords communication between Burgenstock, on one of the Swiss lakes, and a mountain hotel about 722 feet above the lake. The track, of 32-inch gage, has 32-pound T-rails bolted to ten angle-iron ties for each rail length, the ties being embedded in and anchored to a 20-inch bed of concrete. Splice bars extending under the base of the rail are secured by bolts through the upper and lower parts, but the bars extend only half-way up the rail web in order to be clear of the grip or track brakes on the cars; one brake is applied automatically if the tension on the cable ceases or if the operator fails to keep his foot on a pedal which holds the brake off; the other brake is applied by hand and is used to regulate the speed. With two cars at opposite ends of the cable a length of double track is provided to allow the cars to pass. An electric hoist at the top of the incline operates the cable. Current for the control, lighting and telephone communication is taken by the car from overhead wires. At periods of light traffic one car is used for passengers and the other, without an attendant, for baggage, but with heavy traffic each car carries passengers and has an attendant. R.

Gas Company Management to be Taught by Mail by Columbia University.—The teaching of gas company operations through the mails is the aim of a new correspondence course, sponsored by Columbia University and the American Gas Association, which will be given this year under the direction of Prof. Jerome J. Morgan, of the Columbia faculty.

The establishment of this course is the direct result of the increased interest in the manufactured gas business which has taken place during recent years following the application of gas fuel to house heating and to large industrial heating processes.

A considerable number of educational institutions have added courses in gas technology to their curricula, Professor Morgan having conducted such a course at Columbia for the past four years. However, it was realized by the Gas Association that many men employed by gas utilities who would largely benefit from classroom work were excluded by lack of time and geographical location. R.

Commercial Air Routes. (*Machinery*, Aug., 1925, p. 943.)—The extent to which commercial aviation has been carried in Europe will be appreciated when it is mentioned that a total of 13,550 miles of regular air routes are in operation, of which 5400 miles are covered by one company operating a great number of regular services in Central Europe. As examples of the service provided, it may be mentioned that the distance from Christiania in Norway to Dresden in Germany is covered in eight and one-half hours, as compared with about twenty-eight hours by rail and water. From Malmo in Sweden to London, *via* Hamburg and Amsterdam, the air service requires eight and one-quarter hours. This was formerly a 36-hour journey. The distance from Berlin to Stockholm is covered in seven and one-half hours, as compared with twenty-three hours formerly. In 1924 the Junkers' Airplanes, a German corporation operating routes extending over 1300 miles, carried more than 40,000 passengers and 315,000 pounds of mail. R.

Portable Machine for Testing Bricks. (*Technical News Bulletin*, Bureau of Standards, June, 1925, No. 98.)—A portable machine for testing bricks in cross-bend has been designed by Dr. A. H. Stang, of the engineering mechanics section of the bureau, and construction is practically completed. The machine will weigh about 40 pounds. It is hydraulically operated, 16 inches high, 6 inches wide, and 12 inches long.

On account of the proposed change in the A. S. T. M. specifications for brick testing, which will probably eliminate all physical tests except the cross-bend test, the need for such a machine is evident. With this machine an inspector can test bricks on the job and will not need to send specimens to a distant testing laboratory. Delays will thus be avoided and a real indication given of the quality of the brick.

PRESENTATION OF THE FRANKLIN MEDAL AND CERTIFICATE OF HONORARY MEMBERSHIP,

May 20, 1925.

AT THE Stated Meeting of the Committee on Science and the Arts, held February 4, 1925, the following resolutions were adopted:

"*Resolved,* That The Franklin Medal be awarded to Prof. Pieter Zeeman, of Amsterdam, Holland, in recognition of his numerous and important contributions in the field of magneto-optics and particularly of his discovery of the effect of a magnetic field upon the frequencies of the light from a radiating source."

"*Resolved,* That The Franklin Medal be awarded to Dr. Elihu Thomson, of Lynn, Mass., in recognition of his pioneer work in the field of electricity and electrical engineering, and of his numerous inventions in these fields."

THE CONFERRING OF HONORARY MEMBERSHIP.

At the Stated Meeting of The Franklin Institute held January 21, 1925, the resolution of the Board of Managers recommending the election to Honorary Membership of the Hon. William Cameron Sproul, Ex-Governor of the State of Pennsylvania, was unanimously adopted.

STATED MEETING

WEDNESDAY, MAY 20, 1925

3.30 O'CLOCK

PROGRAM

PRESENTATION OF

THE FRANKLIN MEDAL

AND

CERTIFICATE OF HONORARY MEMBERSHIP

TO

PROFESSOR PIETER ZEEMAN, PH.D., SC.D.,

UNIVERSITY OF AMSTERDAM

RECEIVED BY MR. A. LOUDON, SECRETARY

THE ROYAL NETHERLAND LEGATION, WASHINGTON

PRESENTATION OF

THE FRANKLIN MEDAL

AND

CERTIFICATE OF HONORARY MEMBERSHIP

TO

PROFESSOR ELIHU THOMSON, PH.D., SC.D., LL.D.

PRESENTATION OF

CERTIFICATE OF HONORARY MEMBERSHIP

TO

THE HONORABLE WILLIAM CAMERON SPROUL, LL.D.

PAPERS

MAGNETIZATION OF SPECTRUM LINES—REMINISCENCES AND PROSPECTS

PROFESSOR PIETER ZEEMAN, PH.D., SC.D.

PRESENTED BY DR. KARL T. COMPTON

THE MECHANICAL, THERMAL AND OPTICAL PROPERTIES OF FUSED SILICA—FUTURE POSSIBILITIES

PROFESSOR ELIHU THOMSON, PH.D., SC.D., LL.D.

THE PRESENTATION OF THE FRANKLIN MEDAL AND CERTIFICATE OF HONORARY MEMBERSHIP TO DR. PIETER ZEEMAN AND DR. ELIHU THOMSON AND CERTIFICATE OF HONORARY MEMBERSHIP TO THE HON. WILLIAM CAMERON SPROUL.

THE meeting was called to order by Dr. William C. L. Eglin, President of the Institute, who announced that the business of the meeting would be the annual presentation of the Institute's highest award, The Franklin Medal, in recognition of distinguished scientific and technical achievements, and recognized Dr. Karl T. Compton, of Princeton University, who made the following statement concerning the work of Dr. Pieter Zeeman:

Mr. President: I have great honor in presenting for The Franklin Medal, Prof. Pieter Zeeman, Ph.D., Sc.D., of the University of Amsterdam. In support of this presentation I beg to remind you of the extreme importance and fundamental character of the investigations which Professor Zeeman has made in the field of radiation. These investigations led to the first discovery of the electron, to the first measurement of its physical properties, and very recently have led to a theory of spectral emission which promises to be the most powerful method as yet discovered for investigating the inner structure and behavior of atoms.

In 1896 Professor Zeeman first proved that a magnetic field changes the frequency of certain types of radiation from a luminous source. Aided by the electromagnetic theory of Lorentz, he was able thereby to calculate the ratio of the charge to the mass of the vibrating electrical charge from which the light originated. This charge was found to have mass more than one thousand times smaller than the smallest known mass. It was in confirmation of this work by an entirely different method and a few months later that Sir J. J. Thomson found also the electric charge associated with the smaller mass, and these two sets of experiments first established the existence of electrons.

It was soon discovered that various types of spectral lines are affected by the magnetic field in particular ways, so that a study of the Zeeman effect has for many years been one of the most fruitful

methods of investigating spectra and of arranging spectral lines in series.

The applications of the Zeeman effect have extended beyond the laboratory, and by the examination of the spectrum of sun spots and the interpretation of these spectra in terms of the Zeeman effect, Dr. George Ellery Hale proved conclusively that the sun spots are regions of magnetic force, and that such force probably arises from the whirling of electrically charged masses of gas in the sun's atmosphere.

At the hands of Landé and Sommerfeld, the study of the Zeeman effect gives promise of telling us about the arrangement of electron orbits without atoms, and the orientation of these orbits with respect to axes of symmetry in the atom.

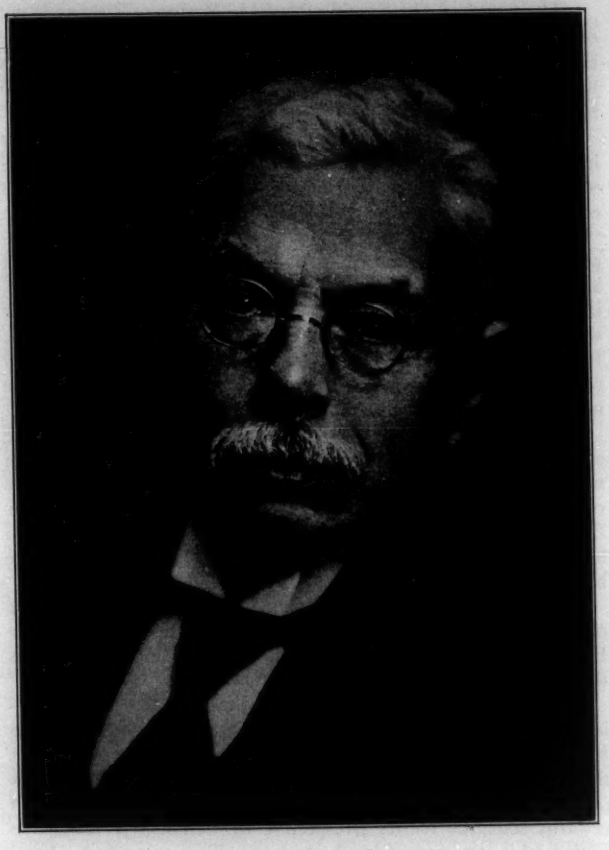
It is a well-recognized principle that one of the most fruitful methods for studying any object is to disturb it and then see how it behaves. In the use of a magnetic field to disturb atoms, Professor Zeeman has opened one of the most fruitful fields of investigation in modern physics.

We regret that it is impossible for Professor Zeeman to be present to receive The Franklin Medal in person from you. We are very fortunate, however, in having with us a fellow countryman of Professor Zeeman, and I have the honor to present to you Mr. A. Loudon, Secretary of the Royal Netherland Legation, who will receive The Franklin Medal in behalf of Professor Zeeman and will transmit it to him through the channels of the Legation.

The President then said: By virtue of the authority vested in me and on the recommendation of the Committee on Science and the Arts, I have pleasure in presenting to you for transmission to Doctor Zeeman, The Franklin Medal and Certificate of Honorary Membership, the highest honor in the gift of the Institute.

Mr. Loudon, in accepting the medal and certificate of honorary membership, said: The Netherland Minister, Jhr. de Graeff, has charged me to express his sincere regret that he is unable to be here this afternoon.

I consider it an extreme honor and pleasure to have been deputed by my Minister to receive The Franklin Medal, on behalf of Professor Zeeman, awarded to him in recognition of his numerous and important contributions in the field of magneto-optics, and particularly of his discovery of the effect of a magnetic field upon the frequencies of the light from a radiating source.



P. Zeeman.

The award of The Franklin Medal to Professor Zeeman is not only an extreme honor to the eminent scientist, but at the same time, to his country, for it means that Professor Zeeman's efforts have been recognized by one of the most celebrated scientific institutions of the world.

Professor Zeeman is no stranger to The Franklin Institute, for he had the honor of being invited in September, 1924, to its centenary, and he then had the privilege of availing himself of its extraordinary hospitality.

The distinction, which is now being bestowed upon him, happily coincides with the twenty-fifth anniversary of his appointment as professor at the University of Amsterdam. On that occasion, in March last, he was greatly honored by his colleagues and pupils who rejoiced over the then already known awarding of The Franklin Medal to Professor Zeeman, and they said that they rejoiced because it recognized the merits of *their* Zeeman, the man whom they not only admire, but whom they equally love.

In a letter which I have just received from Doctor Zeeman he especially mentions how well he remembers the reception which was given to him in September last, and that for that reason he regrets all the more his absence to-day. In this letter Professor Zeeman, moreover, calls my attention to the fact that before him his colleagues, Dr. Kamerlingh Onnes and Doctor Lorentz have been awarded The Franklin Medal.

To-day, for the third time, scientific Holland sees the merits of one of its foremost members rewarded, and while thanking The Franklin Institute for this extreme honor, the Dutch nation feels their distinctions as a national pride.

Mr. Chairman, it is with the highest interest that the Netherland Government follows the work and the achievements of The Franklin Institute, for my Government is fully aware of the fact that science is a very important factor in international life. It is perhaps a mere coincidence that this exalted Institute which rewards scientific merits irrespective of nationality, resides in Philadelphia, the city of brotherly love. This coincidence, however, should not be overlooked or rather it should lay stress upon the fact that science, too, has its international vocation which can bring nations together in an atmosphere of peace and good will. Science is international indeed, but for its progress and development it wants coöperation and stability.

Mr. Chairman, it is with the greatest pleasure that I accept, on behalf of Professor Zeeman, this beautiful medal and this certificate, which I will not fail to forward to him through the intermediary of the Foreign Office at The Hague.

The President then recognized Dr. E. W. Rice, Jr., who presented the following statement of the work of Dr. Elihu Thomson:

It was with the keenest delight that I learned that Dr. Elihu Thomson had been selected to receive The Franklin Medal for this year, and I deeply appreciate the honor of being asked to participate in the happy event. The Secretary informs us that the award of The Franklin Medal to Doctor Thomson is "in recognition of his pioneer work in the field of electricity and electrical engineering and of his numerous inventions in these fields."

Fortunately, Doctor Thomson's achievements in the field of electricity are so well known that I need consume but a few minutes of your time to refresh your memories, or to indicate how wise and fitting has been the action of your Committee in making this award.

Doctor Thomson has long been recognized as one of the world's great pioneers in the electrical field, and it is well known that his contributions have been continued from the pioneer days to the present time, so that, after fifty years of strenuous and fruitful effort, he is still recognized as a leader in his chosen field.

His inventions and engineering work have been the basis of a great manufacturing and engineering industry, and are set forth in some seven hundred United States patents, mostly relating to electrical subjects.

Doctor Thomson was a pioneer in the field of alternating current, and it is particularly interesting that in The Franklin Institute, in this very hall, at a series of lectures given in 1879, he exhibited an alternating current dynamo of his own construction from which he ran two transformers with fine wire primaries connected in parallel to the dynamo line, and the secondaries performing the local work. This was the prototype of the modern transformer system.

This pioneer work was one instance of many where Doctor Thomson's ideas were years in advance of the world's readiness for their reception, and, recognizing this fact, he turned his attention to the development of a system of arc lighting.

His famous 3-coil arc dynamo, with its automatic regulator and other novel features, formed the basis of the successful lighting system put out by the Thomson-Houston Electric Company in the year 1880. This machine was remarkable for its simplicity, ruggedness, flexibility and efficiency. It was the first machine to be entirely automatic in its operation, and would maintain an absolutely constant current flowing in a circuit over the extreme range from full-load to a complete metallic short circuit—a feature possessed by no other machine at that time.

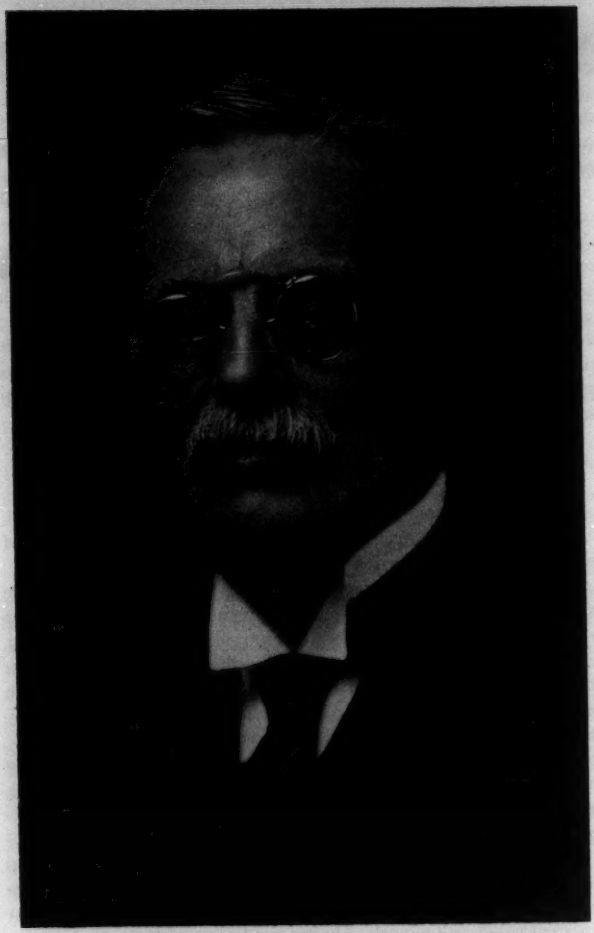
He was the first to utilize a magnetic field to move an electric arc. This idea took many forms, and was first applied in 1881 in connection with a lightning arrester for his arc light system. The principle was immediately extended to the construction of switches in which the magnetic field was used to interrupt the arc formed upon breaking a circuit. All of these devices, known as "magnetic blowout devices," were of fundamental importance, and are still used on an extensive scale, notable applications being found in the controllers for electric street cars, electric trains for elevated roads, and on large electric locomotives.

Later, returning to the alternating current field, he was the first to use oil as an insulating material in transformers, and to make the high-tension alternating current system safe for human beings by introducing the practice of grounding the secondaries of transformers and distributing circuits. In his notable discovery of the so-called alternating current repulsion phenomena, he laid the basis for commercially successful alternating current motors.

A patent granted in 1883 for a reactive coil clearly points out the distinction between a resistance and a reactance, and sets forth the practical value of the reactive coil in regulating and controlling alternating current circuits.

He made the first very high-frequency dynamo in 1890, with a frequency about forty times higher than that hitherto produced in any dynamo. Shortly afterward he originated the method of producing a high-frequency alternating current from a direct current by shunting the arc with inductance and capacity, and published at the time a description of this beautiful apparatus and the theory of its operation.

He also made the first high-frequency transformer, and, as a result of brilliant scientific investigations, developed apparatus



Elihu Thomson

which was afterwards utilized in wireless telephone and telegraph work.

His universal electric meter for recording direct and alternating current energy, and his new electric measuring instruments of all kinds made possible that definite and accurate knowledge needed for the orderly growth of the electrical business.

But Doctor Thomson was not satisfied with even these great contributions to a developing art. In 1886 he gave us a new art—the art of electric welding by the incandescent method. This discovery and its development, spot or line welding, are used for a multitude of services, from the joining of the fine wires which lead the current into the incandescent lamp or the radio valve, to the construction of the hulls of great steamships without rivets. Unweldable metals were easily joined, and complicated and expensive mechanical methods were made simple, cheap and reliable.

He made many important contributions to the field of radiology, and was the first to make stereoscopic X-ray pictures.

He did early pioneer work with the electric resistance furnace, and developed a method of manufacturing that beautiful material, fused quartz, by electrical means, which gives every evidence of being the best yet devised.

He made the first important research into the nature of the laws governing the electric arc. The results of this investigation were published in the FRANKLIN INSTITUTE JOURNAL in 1879, and disclosed, among other things, the important fact that the resistance of the arc varied inversely with the current, which accounted for the instability of an arc unless operated from a circuit having constant current characteristics.

During the years since this first research he has made many other scientific researches, to some of which I have briefly alluded, and has contributed hundreds of articles on scientific and engineering subjects.

This incomplete and imperfect sketch will, perhaps, serve to indicate the extent and variety of Doctor Thomson's knowledge and the range of his mental activities, and the ingenuity and great practical value of his work. He has not been content to make some astonishing discovery or invention and then lapse into comparative quietude, but during his entire life has been a continuous worker. Thomson, perhaps more than any other inventor since the days of

Henry and Faraday, combines in his person profound and accurate scientific knowledge with most extraordinary technical skill.

He has received numerous honorary degrees: Master of Arts, Yale, 1890; Doctor of Philosophy, Tufts College, 1894; Doctor of Science, Harvard, 1909; Doctor of Laws, University of Pennsylvania, 1924; Doctor of Science, Victoria University, Manchester, 1924.

Doctor Thomson received the Grand Prix in Paris, 1889, and again in 1900, for electrical inventions, and was decorated by the French Government as an Officer of the Legion of Honor. In 1904 he received the Grand Prize at St. Louis. He was given the Rumford Medal in 1902, and in 1910, was the first recipient of the Edison Medal. In addition, he has been awarded the Elliott Cresson Medal, the John Fritz Medal, the Hughes Medal of Royal Society, London, and last year, the greatest of all English medals, the Kelvin Medal.

It would therefore seem singularly fitting that he should now be the recipient of The Franklin Medal, given by The Franklin Institute, the scene of his earliest pioneer work in the electrical field. It is with the greatest pleasure that I present to you Dr. Elihu Thomson for the receipt of The Franklin Medal.

The President, in presenting The Franklin Medal and Certificate of Honorary Membership to Doctor Thomson, said: By virtue of the authority vested in me and on recommendation of the Committee on Science and the Arts, I have the honor to present to you The Franklin Medal and Certificate of Honorary Membership in the Institute in recognition of your distinguished services to mankind rendered in the field of applied science. It is a great pleasure to the members of the Institute to bestow on one of its oldest and most honored members the highest award within its gift.

Doctor Thomson, in accepting The Franklin Medal and Certificate of Honorary Membership, said: In acknowledging with a deep sense of appreciation the honor done me in the award of The Franklin Medal, my mind naturally turns back to the early years of my connection with the Institute and its activities nearly half a century ago, and this brings me to another acknowledgment, for I can now see clearly that a great deal of the inspiration for the work which has occupied the years between was probably a direct outcome of the stimulus given by the

Institute and its library at a time when it was most needed, and an indication of what it must have meant to other students in science and the arts. Again on my leaving Philadelphia in 1880, to go to New England and work out the beginnings of what became afterward a great factor in electrical development, I can truly say that no organization was more missed in the transplantation than this society, the Institute, which a few months ago celebrated its one hundredth year. And here I have great pleasure in mentioning the fact that I did not leave Philadelphia alone, for with me went a lad still in his teens, who through all the years following was my able coadjutor and associate, and who, receiving many honors for his work and most exceptional ability, rose from one official position to the other, and finally served as the President of the General Electric Company, the highest honor possible to it. But I know that his heart, like mine, was, through all the vicissitudes of a business life, strongly drawn to the laboratory and its problems, whether of pure or applied science.

I think, too, that if Franklin were here, in the midst of the wonderful advances in electrical science, he would himself treasure the memories of his early electrical work more dearly than those of his other more or less ephemeral activities, for what he did in his favorite science will endure to the end of time on this earth.

It was here in the Old Hall of the Institute (and I hope I may be pardoned for making a few brief references) that perhaps the earliest measurements of the properties and efficiencies of dynamo-electric generators were made in the winter of 1877–1878. As a member of the Commititee on Dynamo-electric Machines, in charge with Prof. E. J. Houston, there was published in the FRANKLIN INSTITUTE JOURNAL early in 1878, the results of our electrical tests.

It was in this Hall that the first transformers, two of them, were set up and operated as they are used to-day in systems of distribution. This was early in 1879, years ahead of actual use of such devices in the electrical art.

It was here also that early in 1877, while lecturing on electricity, an experiment was made by me which gave the first suggestion of what later, in Lynn, Mass., became the art of electric welding.

It has been a great pleasure to return at times and either show or describe to the Institute the more recent work undertaken in

the field which I had followed, largely, I believe, as a result of the interest in its more serious aspects begun here so long ago.

It is then with a feeling something like that of coming home in the afternoon of life that I receive The Franklin Medal, and thank the Institute and its committee that they have seen fit to confer this testimonial, the most significant of the honors which it is in their power to grant. I feel sure that in the second century of the Institute's life, now begun, it will as ever serve to stimulate the love of scientific knowledge and the applications to useful purposes, and so further the general advancement of society, the best of all objects, for truly unless human society benefits by our living in it, we have lived in vain.

The Chairman then recognized Dr. Arthur W. Goodspeed, of the University of Pennsylvania, who, in introducing the Hon. William Cameron Sproul, said:

Mr. President: You have conferred upon me the duty—which I deem an honored privilege—of presenting this approved candidate that he may receive "the Certificate of Honorary Membership in The Franklin Institute."

A loyal and honored son of Swarthmore College, and at present a member of its Board of Managers, the recipient of many honorary degrees from other institutions of learning; farmer, manufacturer, journalist, diplomat, organizer and director of many commercial enterprises and public utilities; holder of many public offices of increasing importance until as a fitting climax he was elected in 1919, Governor of the Commonwealth of Pennsylvania; a member of organizations both social, political and scientific too numerous to name; founder of the Sproul Astronomical Observatory at Swarthmore College; liberal contributor to many educational projects, including the outfitting of expeditions for the observation of solar eclipses, the purpose of which is pure scientific investigation, with no expectation of any useful result either in the near or remote future; a man whose industry and enterprise have made him a marked figure in the world of finance, commerce and education, deeply impressing all who know him with a high estimate of the singular qualities with which nature has endowed him, and with the many qualifying attributes that we have often heard applied to the man whose name this Institute bears, I hereby present, sir, William Cameron Sproul, that he may receive the unusual honor which you have the authority to bestow upon him.

The President in presenting the Certificate said: Governor Sproul: By virtue of the authority vested in me as President of The Franklin Institute, upon the recommendation of the Committee on Science and the Arts, and with the unanimous endorsement of the Board of Managers and the membership of the Institute, I have the honor to present to you the Certificate of Honorary Membership in The Franklin Institute in recognition of your aid in the promotion of science, especially by the erection and equipment of the Sproul Astronomical Observatory of Swarthmore College. Sir, it gives me great pleasure to transmit this Certificate to you.

Doctor Sproul, in accepting the Certificate of Honorary Membership, said: Mr. Chairman: I am deeply sensible of the very unusual honor which has been shown me by my election to honorary membership in The Franklin Institute. I greatly appreciate the compliment of Professor Goodspeed's presentation, and am happy, indeed, to be included among those who have been considered worthy of the particular distinction which I have received. As a citizen of Pennsylvania, proud of her institutions and the attainments of her people, I can think of no higher honor than that which has been given me by this venerable and distinguished organization.

The President then recognized Dr. Karl T. Compton, who presented the paper, "Magnetization of Spectrum Lines—Reminiscences and Prospects," by Dr. Pieter Zeeman (p. 305).

Dr. Elihu Thomson was then recognized, and presented his paper on "The Mechanical, Thermal and Optical Properties of Fused Silica" (p. 313).

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

A METHOD OF DETERMINING THE DEW POINTS OF FUEL-AIR MIXTURES.[1]

By Roy J. Kennedy.

[ABSTRACT.]

A VERY important consideration limiting the proportions of low-volatility constituents permissible in a hydrocarbon engine fuel is the minimum temperature required to keep a mixture of the fuel and air completely vaporized. This temperature is called the dew point of the mixture. This paper outlines a method which has been devised at the Bureau of Standards for determining these temperatures for mixtures of any fuel with air by means of a few measurements on the fuel and on the mixture. The method has been checked by applying it to a variety of gasoline-air mixtures and comparing the results with those of a more direct method.

The theory is based on the assumption that over the small range of pressures and temperatures with which we are here concerned (those occurring in the engine manifold) the first very small fraction of liquid condensing out just below the dew point and in equilibrium with the remaining vapor, is of sensibly constant composition. The Clausius-Clapeyron equation relating the rate of change of vapor pressure with temperature to the heat of vaporization of the first condensate is then applicable, and by means of this relation, the equation of condition for ideal gases, and Dalton's law, a closely approximate expression is derived for the dew point corresponding to any pressure and mixture ratio. It is

$$T = \frac{K_1}{\log P - \log\left(1 + \frac{M_f}{M_a} R'\right) - K_2}$$

where T is the dew point; K_1 and K_2 are experimentally determined constants characteristic of the fuel; M_f and M_a are the average molecular weights of the fuel and of air; R' is the mixture-ratio, that is, the ratio by weight of air and fuel; P is the total pressure exerted by the fuel-air mixture.

* Communicated by the Director.

[1] Scientific Papers, No. 500. Price, ten cents.

The average molecular weights are determined by any of the classic methods, which consist essentially in measuring the quantities p, v, m, and T (the gas constant R being known), in the equation of condition,

$$pv = \frac{m}{M} RT,$$

and from them computing M.

To determine the constants K_1 and K_2, a small quantity of liquid fuel is accurately measured into a partially evacuated glass vapor chamber immersed in a variable-temperature bath, and the temperature is noted at which condensation just appears or disappears on a small spot which is kept a fraction of a degree cooler than the rest of the chamber wall while the bath temperature is decreased or increased. The average molecular weight of the solution having been determined, the partial pressure corresponding to any temperature can be computed. If logarithms of partial pressures are plotted against reciprocals of the corresponding initial absolute temperatures, a very nearly straight line is obtained; two such pairs of values are theoretically sufficient to fix it. From the derivation of the equation for T, K_1 is seen to be the slope of this line, and K_2 is determined by its intercepts.

With the numerical values of the four constants substituted in the equation, it expresses the dew point as a function of the pressure and mixture-ratio of the mixture. Curves are plotted between dew point and pressure for several different values of mixture-ratio for each of four gasolines investigated.

A METHOD OF STUDYING ELECTRODE POTENTIALS AND POLARIZATION.[3]

By H. D. Holler.

[ABSTRACT.]

A RESISTANCE-COUPLED electron-tube amplifier was used to operate an oscillograph for observing the variations in the potential of an electrode without requiring any current from the electrode under investigation. By making oscillographic photographs of the electrode potential at the instant of interrupting a direct current through the cell under investigation it was possible to

[3] Scientific Papers, No. 504. Price, fifteen cents.

obtain a continuous record of the variation in potential. In cases where the polarization potential disappeared slowly enough, distinction could be made between the electromotive force of polarization and potential difference due to resistance.

By superposing alternating current upon the electrode under investigation and the half cell, it was possible, with the use of the amplifier and a separately excited wattmeter, to measure the true alternating potential across the electrode. From this potential and the current passed through the cell, the boundary resistance at the electrode was computed from Ohm's law. This was permissible because the potential and current, as shown by the oscillograph, were in phase, there being a negligibly small capacity effect.

The boundary resistance varied considerably with the different kinds of electrodes. The resistance of platinized platinum, lead, and carbon in sulphuric acid was small; that is, several hundredths of an ohm, while that of smooth platinum and copper in the same electrolyte was high, several tenths of an ohm. The resistance of copper in copper sulphate and zinc in zinc sulphate was also small. The results show that in some cases the electrode potential as measured by the potentiometer when current is flowing is more than 0.2 volt too high because of the potential due to resistance. In the cases where the boundary resistance was high, it decreased rapidly as the current was increased.

FIRE RESISTANCE OF CONCRETE COLUMNS.[3]

By W. A. Hull and S. H. Ingberg.

[ABSTRACT.]

THE study of the fire resistance of concrete columns included fire tests of sixty-two columns under working load and compression test of sixteen comparable columns not subjected to fire tests. A few columns were of plain concrete, others had vertical reinforcement with only a nominal amount of lateral ties. The greater number had vertical reinforcement inside of lateral reinforcement in the form of spirally wound wire, as is now generally used where heavy loads are supported.

Since experience with fires in buildings had indicated that the type of aggregates used in making the concrete had a decided

[3] Technologic Papers, No. 272. Price, twenty-five cents.

influence on the fire resistance, a wide range in mineral composition of the aggregate was introduced. Comparable tests were also made with round and square columns. The general thickness of concrete or other material considered as protection was 1½ inches. Some tests were made with 2½-inch concrete or other protection, with and without embedded metal binder.

The columns were subjected, under a nominal working load, to fire exposure increasing in intensity according to a predetermined time-temperature relation until failure or until the end of four hours, when additional load was applied up to the limit of the furnace equipment (600,000 pounds).

The results bring out clearly the factors on which the fire resistance of concrete columns, as of concrete construction generally, depends. The wide difference in fire effects was determined as due in large part to different mineral composition of the concrete aggregates used. Concrete made with aggregates containing a high percentage of quartz, chert, or granite is likely to crack and spall when subjected to fire of mild or moderate intensity and duration, while those made with calcareous aggregates, such as limestone or calcareous gravel, show little visible effects even from very severe fires. Concrete made with trap rock or blast-furnace slag gives results intermediate between those made with siliceous aggregates and with calcareous aggregates.

The disrupting effects of the fire on concrete made with siliceous aggregates are apparently due mainly to the expansion characteristics of quartz and other forms of silica and minerals containing them. At the inversion point (573° C., 1063° F.) where quartz is transformed from the alpha to the beta form, a large volume change takes place that apparently induces cracking and loosening of the outer concrete early in the test. This appreciably affects the ability of the column to support working load when exposed to fire, although not beyond the point where it functions satisfactorily in this respect under the lighter exposures obtaining with office, residence, and institutional occupancies. Considerable damage to the outer protective concrete takes place that would require repair after fires that do not cause failure or serious permanent impairment of the column strength.

Columns of concrete made with trap rock or blast-furnace slag are subject to less damage from fire exposure with consequent greater ability to come through fires without failure. The best

performance is given by columns of concrete made with limestone or other calcareous aggregates. This is ascribed to freedom from cracking and spalling, and good heat insulating properties both of the calcined and uncalcined material. The heat flow is further retarded by the calcination process itself, which extends nearly through the protective concrete when exposed to severe fires, the change from calcium carbonate to calcium oxide absorbing considerable heat. Such columns with proper amounts of vertical and lateral reinforcement protected by 1½ inches of concrete outside of the steel, resisted test fires comparable with the most severe fire conditions that can reasonably be expected with any building occupancy.

A considerable portion of the investigation was devoted to means for increasing the resistance of columns made with the less favorable concrete aggregate combinations. It was shown that for columns made with siliceous aggregates a large improvement is effected by placing metal ties, such as wire mesh, in the protective concrete, particularly where the thickness is increased somewhat beyond the 1½ inches generally regarded as a minimum protection for concrete columns. Comparable increase in resistance can be obtained by replacing part of the protective concrete with plasters that remain in place during the fire exposure. The effectiveness of plasters subject to cracking, spalling, or other disintegrating effects can be greatly increased by embedding metal ties in them as the protection is placed. Columns thus protected and of concrete made with siliceous aggregates came through test fires equal in intensity and duration to very severe building fires with little loss in strength, the damage being confined mainly to the outer protection.

COMPARATIVE WEARING QUALITIES OF PIMA AND ORDINARY COTTON USED IN MAIL BAGS.[4]

By F. R. McGowan, Charles W. Schoffstall and A. A. Mercier.

[ABSTRACT.]

The general characteristics of Pima cotton are discussed, together with the reasons for attempting to find new uses for this type. The purpose of the investigation was to compare mail bags made from Pima cotton with those made from ordinary cot-

[4] Technologic Papers, No. 277. Price, ten cents.

ton. The full organization used for the construction of this Pima fabric is given. The bags when completed were put into service as catcher pouches for one year. Tests were made before and after, and an examination of the bags was made for punctures and tears. The results show that the Pima cotton mail bags stood the service decidedly better than ordinary cotton bags.

EFFECT OF TWIST ON THE PHYSICAL PROPERTIES OF A NO. 7 YARN.[5]

By F. R. McGowan, Charles W. Schoffstall and A. A. Mercier.

[ABSTRACT.]

THIS investigation was made to determine the most suitable twist to use in making the yarn to be used in the Pima post-office bag investigation. Data were obtained on the relation of the twist to the breaking strength, diameter of the yarn, yarn count, contraction, and angle of twist. While the data were not sufficiently extensive to attempt to fix definite formula for these relations, it is thought that the tabular and graphical relation studied in this investigation will be useful for the cotton manufacturer. The most suitable twist for the yarn to be used in the Pima mail bags was found to be about twelve turns per inch.

TESTING OF FIRE-CLAY BRICK WITH SPECIAL REFERENCE TO THEIR USE IN COAL-FIRED BOILER SETTINGS.[6]

By R. F. Geller.

[ABSTRACT.]

FOLLOWING a conference of Government representatives and users and producers of fire-clay refractories, held at the Bureau of Standards, a voluminous field survey report was obtained through the coöperation of Stone and Webster and refractories of forty-two brands representative of the product as manufactured in the United States were submitted to an extended investigation in the laboratory.

In the laboratory the refractories were subjected to the following tests: (1) *An endurance test* (in which brick were held at 1450° C. for seventy-two hours, both with and without load);

[5] Technologic Papers, No. 278. Price, ten cents.
[6] Technologic Papers, No. 279. Price, twenty cents.

(2) *a reheating test* (in which the change in volume and porosity was determined after the brick had been held at 1400° C. for five hours); (3) *a quenching test;* (4) *the standard A.S.T.M. load test,* and to modifications of this test; and (5) the *softening points* were determined by the cone method; and brick of each brand were *analyzed chemically* and several *examined petrographically.*

As a result of the laboratory work, it was found that a close relation existed between data obtained in the endurance, reheating, quenching, and softening point tests, and that these depended to a remarkable extent on the chemical composition. The results indicated that a refractory which would successfully withstand fifteen quenchings from 850° C. to running water had a softening point equivalent to at least that of cone 32; that the linear change in the endurance test would not exceed 2 per cent. and when transversely loaded the deflection would not exceed 10-32 inch; that the absorption after the reheating test would lie between 6 and 10 per cent.; and also that the refractory should be composed of raw materials containing not more than 4 per cent. flux and 20 per cent. uncombined quartz. The results also favor the dry-press process for manufacturing brick.

It was found that refractories which appeared of highest quality in the laboratory did not always give the highest service, but this was to be expected since no two brands of refractories were subjected to similar service conditions. The field survey showed, however, that in practically every instance brick fail primarily through erosion, indicating lack of refractoriness and resistance to the fluxing action of molten coal ash. The one exception is the suspended arch in which the refractories fail mainly by spalling. In addition, the data from the survey indicate that where the life is relatively long the brick fail by erosion while, with a short life, the failure is due to combined erosion and spalling.

RECLAMATION OF GASOLINE USED IN DRY-CLEANING.[1]

By C. C. Hubbard.

[ABSTRACT.]

THIS paper outlines and discusses briefly the processes that have been used in the dry-cleaning industry for the reclamation of used gasoline, the solvent in most general use. Results are

[1] Technologic Papers, No. 280. Price, five cents.

reported of experimental studies in the laboratory and in dry-cleaning plants and large-scale tests in dry-cleaning plants. A process is recommended and described in detail for the rapid and economical purification and recovery of gasoline in large or small plants. The following is an outline of the process: Mix thirteen pounds of activated carbon with about eight to ten gallons of gasoline, either new stock or the dirty solvent, and pump into a 200 to 250-gallon cone-bottom tank. Dissolve twelve pounds of crystalline trisodium phosphate in twelve gallons of water, and pump the solution into the tank containing the carbon. Now pump the dirty solvent into the tank until nearly full, agitate for fifteen minutes by means of a mechanical stirrer or a 1½-inch centrifugal pump. Let settle fifteen to thirty minutes, and then run off the clear, colorless solvent through a pipe, just above the sludge line, to the underground storage tank. The same charge of activated carbon and phosphate may be used for treating a number (five to ten) of tanks of the dirty solvent, depending upon the nature and amount of the soiling matter present. When the recovered solvent shows a light straw color, the sludge should be run out of the tank into a barrel or other vessel. The tank is now washed out with water and recharged as above outlined. The temperature of the solvent being treated should be kept between 50° and 80° F. The gasoline retained by the sludge is practically all recovered by adding an equal volume of water, stirring, allowing to stand twelve to twenty-four hours, and then siphoning off the upper or gasoline layer.

MALLEABILITY AND METALLOGRAPHY OF NICKEL.[*]

By P. D. Merica and R. G. Waltenberg.

[ABSTRACT.]

IN THE manufacture of "malleable" products of nickel and certain nickel alloys, such as forgings, rolled shapes, and castings, certain rather unusual metallurgical treatments of the molten metal are resorted to in order that the cast product may be sufficiently malleable and ductile for the subsequent forging operations. The principal feature of these treatments is the addition to the molten metal, before casting, of manganese and magnesium. Ordinary

[*] Technologic Papers, No. 281. Price, ten cents.

furnace nickel, without these additions, will give a casting, in general, which is not malleable either hot or cold.

This fact has long been known and prevented the commercial development of pure nickel in wrought forms for many years after the isolation of nickel, and even after the beginning of its commercial production and development for other purposes. It was not until about 1880 that methods for treating nickel to make it malleable were discovered. To Th. Fleitmann is due the credit for the discovery in 1878 that the addition of metallic magnesium in small amounts to molten nickel secures the production of nickel which is malleable, both hot and cold. Others have in the meantime suggested the use of manganese which, however, was found to be less effective than magnesium.

The present practice in the production of pure malleable nickel, as well as of many high nickel content alloys, such as Monel metal, chromel, nichrome, etc., combines the use of both manganese and magnesium. Manganese is added first in amounts from 0.25 to 2.00 per cent., followed by the addition of approximately 0.1 per cent. of metallic magnesium. The resulting metal is extremely malleable, and can be subjected to practically all usual forming operations.

Although this practice is successful in restoring malleability to furnace nickel and has been established for years, the mechanism of its action has remained somewhat obscure as well, indeed, as the reason for the lack of malleability in untreated nickel. The effect of magnesium has been attributed both to "deoxidation" of the metal and to its "degasification." For some time it has been realized that these explanations could not be adequate and it was for the purpose of throwing more light upon the structural and chemical mechanism of variations in the malleability of nickel that this investigation was undertaken.

It has been possible to demonstrate that the lack of malleability, in ordinary nickel, melted and cast without treatment, is due primarily to the presence of sulphur, in amounts as low as 0.005 per cent. This sulphur is combined with nickel as Ni^3S^2 which forms a eutectic with nickel melting at 630° C. The structural habit which this eutectic sulphide takes is that of intercrystalline films completely or partially surrounding each metallic grain of nickel (or alloy). It is obvious that the presence of

such films, brittle at low temperatures and liquid at higher ones, effectually destroys the intercrystalline cohesion of the grains and, hence, the malleability of a metallic mass containing them.

Nickel containing less than 0.005 per cent. of sulphur is malleable without any treatment whatever, and even when containing substantial amounts of gases or of nickel oxide. With these lower percentages of sulphur it was not apparently possible to make nickel non-malleable with the usual amounts of impurities. With the sulphur above 0.005 per cent., however, the nickel is consistently brittle and only the magnesium treatment, with or without the manganese treatment, can completely restore its natural malleability. Manganese additions alone improve the malleability of sulphur-bearing nickel, but not to the extent that magnesium does.

This effect of both manganese and magnesium is due to the formation of manganese or of magnesium sulphides from the nickel sulphide. The manganese sulphide has both a higher melting point (as a eutectic) and a less critical form of distribution than the nickel sulphide. Magnesium sulphide has an extremely high melting point—greater than that of nickel itself—and forms in small, equiaxed particles distributed uniformly throughout and within the metallic grains. The presence of MgS thus exerts practically no detrimental effect upon the crystal cohesion, and consequently upon the malleability of nickel.

These facts are demonstrated by various means, microscopic, thermal, and chemical, and the evidence from all sources is quite conclusive.

In connection with the principal feature of this investigation a brief study was made of the nickel, nickel oxide equilibrium. It was found that nickel oxide, NiO, forms a simple eutectic series with nickel, the eutectic containing 1.10 per cent. NiO and melting at 1438° C. The oxide, NiO, melts at about 1650° C. and does not appear to dissociate at this or lower temperatures. Nickel containing less than 0.005 per cent. sulphur and as much as the full eutectic amount of NiO, is quite malleable and ductile, resembling copper in this respect.

This investigation was carried out under a fellowship maintained at the Bureau of Standards by The International Nickel Company.

TABLES AND GRAPHS FOR FACILITATING THE COMPUTATION OF SPECTRAL ENERGY DISTRIBUTION BY PLANCK'S FORMULA.[9]

[ABSTRACT.]

VERY frequently it has been necessary to compute the spectral distribution of a "black body" in the visible spectral region at some particular temperature from Planck's formula:

$$E_\lambda = \frac{C_1 \lambda^{-5}}{e^{\frac{C_2}{\lambda\theta}} - 1} \qquad (1)$$

E_λ is the energy of wave-length λ, at any temperature θ (degrees absolute); C_1 and C_2 are constants. Such computation consumes much time and labor. In consequence, the following short-cuts in the way of tables and graphs have been devised. For the benefit of those who have similar computations to make, it was thought worth while to publish these tables and graphs. The above equation has been combined with that of Wien, connecting the temperature with the wave-length at which the maximum energy occurs, namely,

$$\lambda_m \theta = A, \text{ a constant.} \qquad (2)$$

The resulting formula

$$\frac{E_\lambda}{E_m} = \left(\frac{A}{\lambda\theta}\right)^5 \left(\frac{C_2}{e^A} - 1\right) \left(\frac{C_2}{e^{\frac{C_2}{\lambda\theta}}} - 1\right)^{-1} \qquad (3)$$

expresses the relative energy as a function of $\lambda\theta$ alone. Using (3), a table has been computed giving the values of E_λ/E_m to four significant figures for a wide range of values of $\lambda\theta$ ($A = 2890$ micron degrees; $C_2 = 14{,}350$ micron degrees).

For any given temperature, the wave-lengths in the visible, and also partly in the ultra-violet and infra-red regions, corresponding to these values of relative energy, can readily be obtained from the products $\lambda\theta$. Hence, the spectral energy curve can be plotted at once.

It is often desirable to know the energy values for wave-lengths 10 $m\mu$ apart. These values can be read with accuracy from the curves just mentioned, if they have been plotted to a suitable scale. By using a suitable factor, the scale can be changed to give the value 100 at 590 $m\mu$ or at any other wave-length desired.

[9] Miscellaneous Publication No. 56. Price, thirty-five cents.

Two sets of tables have also been made up, each for thirty-eight temperatures, in which the energy values computed directly from Wien's and Planck's formulas are recorded for the wave-lengths 400 to 720 $m\mu$, at intervals of 10 $m\mu$. These two tables have different relative energy scales, one set having the energy equal to 100 at 590 $m\mu$, the other equal to 100 at 560 $m\mu$. The temperature range is from 1000° to 28,000° K. The accuracy of these values is within 0.15 per cent.

These tables were found inadequate as they provided no means for obtaining the energy distribution at intermediate temperatures. To meet this need a series of isochromatic curves has been plotted utilizing the data for which the energy assumes the value 100 at 560 $m\mu$. In these, the relative energy has been plotted against the absolute temperature, and one complete curve drawn for each of the thirty-three wave-lengths. To obtain the desired accuracy (within 0.33 per cent.), the curves have been plotted in separate sections, to suitable scales, on 40 by 50 cm. sheets. The temperature scale has been chosen so that values may be read to within 1° for the range 1000° to 8000° K., and to within 5° for the range 8000° to 28,000° K. The precision in reading the energy values should be better than 0.33 per cent. except for the small portions of the curves lying below the ordinate 3.5, and possibly also on very steep parts or near the line $\theta = 1000°$ K. The curves are reproduced in their original size so as to permit reading to this accuracy. From these graphs, the energy distribution for the visible region can be obtained in a few minutes for any temperature whatever in the range specified.

1924 REPORT OF THE NATIONAL SCREW THREAD COMMISSION.[10]

[ABSTRACT.]

THE 1924 Report of the National Screw Thread Commission is a revision of the Progress Report published in 1921 (M. 42, Bureau of Standards, January 4, 1921). The material has been rearranged and extensively revised and several new sections have been added. The report contains specifications for bolts, nuts, and commercial tapped holes, for a coarse and a fine thread series of threads made to four classes of fit; specifications for threads of

[10] Miscellaneous Publication No. 61. Price, thirty-five cents.

special diameters and pitches; fire-hose threads; small-hose threads; pipe threads; threading tools; tap-drills, and gauges.

REPORT ON RECOMMENDED MINIMUM REQUIREMENTS FOR MASONRY WALL CONSTRUCTION.[11]

[ABSTRACT.]

INVESTIGATIONS by the Department of Commerce Building Code Committee and other agencies have disclosed that existing building code requirements for masonry wall construction are as a rule unnecessarily conservative, resulting in considerable waste of labor and materials and increased building cost. Much additional information on the strength and fire resistive qualities of masonry has become available in recent years through efforts of various research and testing organizations. This, together with the consensus of experience and opinion of several hundred experienced builders, was utilized by the committee as a basis for new code requirements which are recommended for adoption by states and cities drafting or revising building codes.

The proposed requirements cover all types of masonry materials. They define, for the purposes of the report, certain terms not uniformly interpreted in the industry and regulate the height, spacing of lateral support, thickness, working stresses and quality of materials for solid brick walls and those of hollow construction, walls of hollow units, both clay and concrete, stone and plain concrete.

Requirements are given for the construction of fire walls and fire division walls and of masonry partitions, both bearing and non-bearing.

One article is devoted to masonry wall requirements; another to new types of masonry construction which may be developed; and still another to the precautions which should be observed in lining or increasing the height of existing walls.

The appendix to the report summarizes various investigations showing the lack of present code uniformity and presents much information on the strength of masonry as established by various test sources and as affected by various factors, such as workmanship, bond, strength of units, etc.

[11] Special Publication, Building and Housing Division. Price, fifteen cents.

A selected bibliography gives references to principal sources of information on masonry construction.

It is expected that adoption of the committee's recommendations will result in saving many millions of dollars annually in the cost of buildings.

Tetraethyl Lead Poisoning.—THOMAS MIDGLEY, JR. (*Ind. and Eng. Chem.*, 1925, **17**, 827–828), discusses the hazard to health from the presence of tetraethyl lead in gasoline. The symptoms produced by this compound are, in the order of their appearance: Subnormal blood-pressure, body temperature, and pulse-rate; sleeplessness; loss of body-weight; nausea; tremor; and delerium tremens. These symptoms are entirely different from those of common industrial lead poisoning. The first three symptoms do not indicate any danger to the patient; and speedy recovery occurs if he be removed from proximity to the tetraethyl lead. Some danger exists if the symptom of sleeplessness has developed; the treatment then includes life in the open air with moderate exercise and freedom from exposure to tetraethyl lead; soporific drugs should not be used. The actual hazard is in the manufacture and handling of tetraethyl lead. The great danger lies in the fact that the poisoning is not acute, but is slow and cumulative. No great precautions are necessary after tetraethyl lead has been mixed with gasoline, the ratio being 1 part in 1300. The resulting product is colored with an aniline dye, and should be used only as a motor fuel, never for cooking or cleansing purposes. It is stated that the exhaust from motors using this gasoline, when mixed with air and then breathed, does not produce lead poisoning.

J. S. H.

Toxicity of Synthetic Methanol.—REID HUNT, of Harvard University (*Ind. and Eng. Chem.*, 1925, **17**, 763), has studied the action of synthetic methanol upon animals. The results, qualitatively and quantitatively, were the same as were produced by pure methyl alcohol manufactured from wood distillates. Use of the synthetic methanol as a beverage or as an adulterant in beverages will produce blindness and even death. Administration of repeated non-lethal doses of ethyl alcohol gives rise to a certain tolerance for that compound. Administration of repeated non-lethal doses of methyl alcohol (methanol) has a cumulative effect, the animal becoming more deeply poisoned with each dose.

J. S. H.

New Amino Acid.—S. B. SCHRYVER, H. W. BUSTON, and D. H. MUKHERJEE (*Proc. Royal Soc.*, 1925, **98**, B, 58–65) have isolated a new amino acid from the products of hydrolysis of certain proteins: Gelatin, fish gelatin, isinglass, edestin, and proteins of oats and cabbage leaf. This amino acid is a hydroxylysine, and probably has the formula: $CH_2NH_2.CH_2.CH_2.CHOH.CHNH_2.COOH$.

J. S. H.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

STATIC MARKING ON MOTION PICTURE FILM.[1]

By J. I. Crabtree and C. E. Ives.

THE nature, causes, and methods of prevention of static markings on motion picture film are discussed. Static discharges are classified into silent and disruptive. The quantity of static electricity produced on motion picture film depends on: (1) The electrical conductivity of the film base and the substance rubbing the base; (2) the amount of friction produced; (3) the conductivity of the air. The effect of humidification on the property of film to give static markings depends on (*a*) the relative humidity and temperature of the air, and (*b*) the time of exposure of the film to the air. Data are given on both factors. Several types of static markings are illustrated and described.

During handling, static markings may be produced either in the camera or in the laboratory when winding the film on racks, and during the processing and printing. Camera static may be prevented by removing all sources of friction, by making all camera parts electrical conductors, by re-humidifying the film, and by conducting the combination products of an alcohol lamp into the camera chamber. Laboratory static occurs as rack static, developing room static, the result of electrification of negative film in the cutting room, and printer static. Methods of preventing static are avoidance of friction; humidification of the film; humidification of the air in the printing room; and humidifying the negative previous to printing. Over-humidification causes troubles from moisture spots, sticking together of the wound film, and softening of the emulsion.

Use of Kelp as a Food.—J. W. TURRENTINE, of the U. S. Department of Agriculture (*Scientific Monthly*, 1925, **20**, 27–39), recommends that kelp be used in the diet in order to prevent, control,

* Communicated by the Director.

[1] Communication No. 236 from the Research Laboratories of the Eastman Kodak Company, and published in *American Cinematographer*, 6: July, 1925, p. 7.

and overcome goitre. Goitre, in either its simple form, or the more advanced, toxic, or exophthalmic form, is primarily due to disturbed function of the thyroid gland as a result of lack of iodine in the diet. It is endemic in certain areas of the United States, chiefly the region of the Great Lakes and the extreme Northwest. Inorganic iodine compounds have been used for its prevention and treatment. The giant kelp of the Pacific, *Macrocystis pyrifera,* is comparatively rich in iodine. In the analysis of twenty-nine samples, the iodine content of the dehydrated kelp ranged between 0.17 and 0.41 per cent., with an average of 0.26 per cent. The processed kelp may readily be used in the diet as a means for the prevention and cure of goitre. Clinical experience has shown the value of kelp in the treatment of goitre. In fact, goitre is a preventable disease. J. S. H.

Sulphide and Selenide of Nitrogen.—H. B. VAN VALKENBURGH and JOHN C. BAILAR, JR., of the University of Colorado (*Jour. Am. Chem. Soc.*, 1925, **47**, 2134–2137), have prepared nitrogen tetrasulphide by passing dry ammonia gas into a solution of sulphur monochloride in ether at the temperature of melting ice. They prepared nitrogen tetraselenide in a similar manner, using a solution of selenium monochloride in carbon disulphide. Both compounds are crystalline solids; their respective molecular weights were determined by the cryoscopic method, using benzene as a solvent for the tetrasulphide and glacial acetic acid as a solvent for the tetraselenide. The results showed the respective molecular formulæ to be N_4S_4 and N_4Se_4. Both the tetrasulphide and the tetraselenide form compounds with ammonia. J. S. H.

Scientific Knowledge of the American Indian.—JAMES A. BRANEGAN (*Jour. Chem. Education*, 1925, **2**, 588–592) demonstrates that the American Indian had an extensive knowledge of applied science. He applied the cleavage of minerals in the manufacture of arrow-heads and tools. He was familiar with the cleansing action of alkalies, and the preparation and use of glue and pigments. He fertilized his corn fields with dead menhaden fish. He knew how to dye fabrics, tan leather, and manufacture pottery. His materia medica contained wintergreen, coca, cinchona, and jalap; knowledge of these drugs has led to the use of such compounds as the inorganic and organic salicylates, cocaine, and the quinine group of alkaloids in modern medicine. The Indian used physical therapy and psychotherapy in the treatment of the sick. J. S. H.

Hydrobromic Acid.—D. T. EWING and HUGH A. SHADDUCK, of Michigan State College (*Jour. Am. Chem. Soc.*, 1925, **47**, 1901–1904), find that an aqueous solution of hydrogen bromide, boiled under a pressure of 760 mm. of mercury, yields a distillate which contains, on the average, 47.795 per cent. of absolute hydrogen bromide, and boils at approximately 125° C. J. S. H.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

THE PREPARATION OF 2-AMINOANTHRAQUINONE FROM PHTHALIC ANHYDRIDE AND CHLOROBENZENE.[1]

By Max Phillips.

[ABSTRACT.]

IN THE preparation of chlorobenzoylbenzoic acid from phthalic anhydride, chlorobenzene, and aluminum chloride, the most favorable yield is obtained when the molal ratio of phthalic anhydride to aluminum chloride is 1 : 1. To carry out this preparation successfully an excess of chlorobenzene should be used, about 4 to 5 mols to 1 mol of phthalic anhydride. The optimum reaction temperature is 100° C. The yield of chlorobenzoylbenzoic acid is about 77 per cent. of the theoretical.

The conversion of chlorobenzoylbenzoic acid into 2-chloroanthraquinone may be brought about by heating it at 150° C. for four hours with sulphuric acid (specific gravity 1.84). The yield is practically quantitative—97 per cent. of the theoretical.

The various experiments on the preparation of 2-aminoanthraquinone from 2-chloroanthraquinone indicate that the optimum experimental conditions are as follows: Temperature, 220° C.; reaction period, six hours; concentration of ammonia with respect to 2-chloroanthraquinone, 20 : 1, although a 15 : 1 ratio gave nearly as good results. The 2-aminoanthraquinone obtained under these conditions is 95 per cent. pure and the yield is 91 per cent. of the theoretical. The addition of catalysts, such as copper sulphate or copper powder, to the reaction mixture is undesirable.

AZO DYES FROM ALKALOIDS OF IPECAC ROOT AND THEIR IDENTIFICATION BY MEANS OF THE SPECTROSCOPE.[2]

By S. Palkin and H. Wales.

[ABSTRACT.]

A METHOD for the identification of phenols described in a recent paper has been extended to apply to certain alkaloids of ipecac. Azo dyes from these alkaloids of ipecac have been pre-

* Communicated by the Chief of the Bureau.

[1] Published in *Ind. Eng. Chem.*, 17 (July, 1925) : 721.

[2] Published in *J. Am. Chem. Soc.*, 47 (July, 1925) : 2005.

pared and measurements made of their absorption spectra in three different solvents. A number of characteristic curves have been thus obtained for cephæline and emetamine, the absorption spectra of which can be used for their positive identification, even in the presence of a considerable quantity of other drugs, if not unduly complicated by interfering substances.

EFFECT OF TEMPERATURE AND TIME OF STORAGE ON THE PHYSICAL PROPERTIES OF UNDEVELOPED BROWN PRINT PAPER.[2]

By T. D. Jarrell and F. P. Veitch.

[ABSTRACT.]

COATERS and users of brown print paper should keep undeveloped sensitized paper at a temperature not higher than 35° to 40° F. in order to conserve its durability.

The effect of the commonly employed brown print sensitizing materials on the folding endurance, bursting, and wet tensile strength of paper was investigated. At intervals of one to twenty weeks after storing the undeveloped coated rolls of paper at 35° to 40° F., 55° to 60° F., 70° F., and 86° F., samples were taken from the various rolls, and developed, washed, and air dried. The physical tests made on these samples showed that the temperature at which undeveloped coated brown print paper is kept between the period of coating and drying and the time of developing and washing influences the effect of the sensitizing materials upon the physical properties of the paper.

Undeveloped brown print paper can be kept at 35° to 40° F. for at least five months without any deterioration in strength. As the temperature increases, however, the deterioration becomes marked.

When stored for two weeks at 55° to 60° F. the folding endurance is decreased about 30 per cent., and the bursting strength is decreased about 5 per cent. The folding endurance and bursting strength are decreased about 45 per cent. and 8 per cent., respectively, when stored for two weeks at 70° F. When stored for two weeks at 86° F. the folding endurance is decreased about 80 per cent., and the bursting strength is decreased about 20 per cent. As the period of storing the undeveloped coated

[2] Published in *Paper Trade J.*, **80** (May 14, 1925) : 56.

paper at these temperatures is prolonged, the folding endurance and bursting strength progressively decrease.

PROTEINS OF WHEAT BRAN.

II. DISTRIBUTION OF NITROGEN, PERCENTAGES OF AMINO ACIDS AND OF FREE AMINO NITROGEN: A COMPARISON OF THE BRAN PROTEINS WITH THE CORRESPONDING PROTEINS OF WHEAT ENDOSPERM AND EMBRYO.[4]

By D. Breese Jones and C. E. F. Gersdorff.

[ABSTRACT.]

THE proteins of wheat bran, consisting essentially of a prolamin, a globulin, and an albumin, have now been analyzed by the Van Slyke method, and the distribution of nitrogen and the percentages of the basic amino acids have been estimated. The percentages of tyrosine, tryptophane, and cystine have also been estimated by colorimetric methods. The wheat bran proteins, in general, are characterized by a high content of the basic amino acids. This is particularly true of the albumin and globulin. The quantity of basic amino acids found in the globulin exceeds that of most other vegetable proteins which have been studied, The following percentages of amino acids were found: (1) In the *prolamin*—cystine, 2.29; arginine, 4.41; histidine, 0.84; lysine, 2.45; tryptophane, 1.37; and tryosine, 3.38; (2) in the *albumin*—cystine, 3.29; arginine, 10.04; histidine, 2.57; lysine, 4.51; tryptophane, 4.76; and tryosine, 4.20; and (3) in the *globulin*—cystine, 1.52; arginine, 14.13; histidine, 2.76; lysine, 11.84; tryptophane, 2.85; and tyrosine, 3.69.

Marked differences were found between the bran proteins and the corresponding proteins of the wheat embryo and endosperm, in respect to their elementary composition, distribution of nitrogen, and amino acid content.

The significance of the high percentages of the so-called nutritionally essential amino acids found is pointed out with respect to the nutritive value of the bran proteins.

Statisticians Measure Crops from Train with Crop-Meter. (U. S. Department of Agriculture Clip Sheet, No. 374, August 24, 1925.)—A device for measuring the acreage of various agricultural crops for comparative reports and charts has been successfully

[4] Published in *J. Biol. Chem.*, 64 (June, 1925): 241.

adapted to a railway train by statisticians of the Department. The instrument is in the nature of an automobile speedometer and when attached to the gear of the railway car measures and records the number of feet of each kind of crop along the right of way. It was designed in 1923 for use on an automobile and was first used successfully in that capacity.

The instrument, besides having a regular mileage meter, such as that on an ordinary speedometer, has twelve special dials—one for each kind of crop—with a set of push buttons which throws them into gear when needed. For instance, when, during the train journey, a field of cotton is being passed the button indicating cotton is pressed and the number of feet of cotton along the road in that particular field is measured and recorded. If the next field is corn, the operator presses the corn button, and the number of feet in that crop are measured and recorded. If the next field should happen to be idle land, the idle-land button is pushed.

The first railway crop-meter measurements were made recently by a department statistician who made a 279-mile trip on a Georgia railway line. The data thus collected can be used to compare the percentage of one crop with another any year and also the percentage of one crop one year with the same crop in other years by repeating the trip over the same route.

Germanium Glass.—L. M. DENNIS and A. W. LAUBENGAYER, of Cornell University (*Jour. Am. Chem. Soc.*, 1925, **47**, 1945–1947), have prepared a series of glasses in which the silica has been entirely replaced by germanium dioxide. A germanium glass has a lower melting point and a higher refractive index than the corresponding silica glass. J. S. H.

New Oxide of Nitrogen.—R. LEONARD HASCHE, of the University of California (*Jour. Am. Chem. Soc.*, 1925, **47**, 2143–2148), has prepared the compound which is formed by the reaction between nitric oxide and oxygen at the temperature of liquid air. It is a pale green solid which decomposes just above the boiling point of oxygen. Its formula is $(N_3O_4)_2$. It probably is di-trinitrosyl peroxide. J. S. H.

Surface Devitrification of Quartzware.—According to FRANK C. VILLBRANDT, of the University of North Carolina (*Ind. and Eng. Chem.*, 1925, **17**, 835–837), the frosting or devitrification, which appears on used laboratory apparatus of fused quartz, is a surface effect. It is frequently due to deposition of slag particles in the surface of the ware, and produces brittleness. The surface devitrification may be removed by treatment with hydrofluoric acid, and the life and serviceability of the quartzware thereby be greatly increased. J. S. H.

NOTES FROM THE U. S. BUREAU OF MINES, DEPARTMENT OF COMMERCE.*

MINE TIMBER ECONOMIES.

By Harry E. Tufft.

A FIELD study of the life of timber in mines, the principal causes of its failure, and means of prolonging life, has been conducted by this bureau in coöperation with the U. S. Forest Service. It was found that life of timber in mines, while ranging from a few months to many years, averages only about three to five years. The main causes of destruction are decay and breakage; minor quantities are destroyed by abrasion and fire. Decay is the chief agency of destruction, and much breakage and premature failure that is attributed to crushing, is in timbers that have been materially weakened by decay, and would have served the mechanical life of the opening if decay had not set in. In the mines examined, decay was observed to be most severe in humid, warm, stagnant atmospheres, and rare in dry, well-ventilated, cool places. Alternating conditions of dryness and humidity favor rapid decay. The atmospheric conditions of most mines are very favorable to the rotting of timber placed therein.

Timbers properly treated with a suitable wood-preservative do not decay. In some deep mines, crushing destroys much timber before decay has had a chance to weaken it, and here treatment could not benefit. Mine operators that have had experience with treated timber are convinced that it pays to treat timbers that are to be placed in the more permanent openings. Timber to be treated should be peeled, piled carefully, and well seasoned. Green or unseasoned timber is difficult to treat.

Very little timber, it was learned, is salvaged in mines of this country. Some coal mines make an effort to recover props, and in general take up and re-use mine ties from tracks laid in temporary headings. A few metal mines also recover some of the timber used in drifts and stopes.

In general, timber convenient to the mines is becoming scarcer and more costly from year to year, particularly in mining districts

* Communicated by the Director.

of the East and mid-West. In order to conserve existing supplies of timber, and to eliminate the cost of expensive retimbering jobs, timber that will have to be replaced through decay, should be treated.

Further details are presented in Bureau of Mines Bulletin 235, recently issued, entitled "Mine Timber, Its Selection, Storage, Treatment, and Use," by R. R. Hornor and Harry E. Tufft, of the bureau, with a chapter on methods of prolonging life of mine timber, by George M. Hunt, of the U. S. Forest Products Laboratory.

PYROTANNIC ACID METHOD FOR DETERMINATION OF CARBON MONOXIDE.

By R. R. Sayers and W. P. Yant.

CARBON MONOXIDE (CO) may be formed in many places and inhalation of this insidious gas is a frequent and widely distributed cause of poisoning that ranges in severity from headache and lassitude to unconsciousness and death. As cases of this type of poisoning often occur from the most unsuspected sources, it is essential to have suitable means whereby the true condition can be ascertained. Quick, accurate determination is not only of value for making diagnoses and giving proper treatment, but for investigating the causes and conditions under which the poisoning occurred, as well as providing means for examining doubtful atmospheres to prevent and guard against the recurrence of poisoning.

The only infallible diagnosis of CO poisoning is made by examination of the blood for carbon monoxide hemoglobin, HbCO. A mere qualitative examination for this compound will indicate whether or not CO is present, but in view of the obvious desirability of knowing whether or not CO is the primary cause of the condition of the patient, it is necessary to make a quantitative determination of the HbCO present.

Methods have been devised for the quantitative analysis of CO when present in blood and in air in quantities large enough to be dangerous to the health and safety of a person. Some of them are suitable as to accuracy, yet all have some objectionable features in that they require elaborate and expensive apparatus, and special technique and training on the part of the analyst, or

are too delicate and cumbersome for field use. The last factor is important in investigations pertaining to the cause, diagnosis, and treatment of this type of industrial and domestic accident.

The Bureau of Mines, in its investigation of many cases of industrial and domestic poisoning from CO, found it necessary to develop a method and apparatus that could be immediately taken to the scene of a poisoning, and which would give accurate results as to the CO in the blood and in the air. The method has been used frequently during the past two years in the investigation of fatal and non-fatal cases of poisoning from gas stoves, automobile exhaust gases, and blast-furnace gas; also in the analysis of air in vehicular tunnels and in mines after blasting and during rescue operations after a mine explosion. It has been used in the laboratory for experimental investigation of CO poisoning of men and animals and has also been used with equal success by other investigators and by corporations both in America and in foreign countries. In all of this work the method has been found very reliable and accurate, and admirably fulfills requirements for the examination of blood and air. Its simplicity and ease of operation make it well suited to the needs of hospitals, industrial surgeons, safety engineers, coroners, departments of public safety, boards of health, and other allied organizations.

Further details will be found in Technical Paper 273, just issued by the Bureau of Mines.

METALLURGICAL TREATMENT OF ZINC-RETORT RESIDUES.

By B. M. O'Harra.

The residues resulting from the retort distillation of zinc ores have 25 to 75 per cent. of the weight of the original ore and contain 5 to 15 per cent. zinc. In round numbers, 450,000 tons may be considered the present normal production of zinc by retort smelters. On the assumption that about one ton of zinc is produced from two tons of concentrate, there must be normally about 900,000 tons of concentrate treated annually in retort smelting plants. If the weight of retort residues is estimated to be 40 per cent. of the weight of the concentrate smelted and is assumed to have an average zinc content of 8 per cent., we can calculate that approximately 360,000 tons of residues, containing about 28,800 tons of zinc, are produced annually in the United

States. Besides, large accumulations from past operations are available for treatment whenever treatment becomes profitable.

In addition to zinc, the residues contain much unburned coal, carbonized or converted to coke during the distillation process; residues from most western zinc ores also contain lead and silver.

The treatment of these residues for the recovery of the contained coke and metal values presents a fertile field for investigation and has received the attention of many metallurgists, as is manifest from the number of methods that have been tried and of processes that have been patented.

During the year 1922 the Bureau of Mines received so many inquiries concerning the possibility of profitably treating retort residues that an investigation of residue utilization was deemed advisable. As a first step a survey was made of the processes already tried and of those now in use. The treatment of broken retorts and condensers was included in the survey as a closely related subject. This survey showed that there was little occasion for further experiments of a general nature, but that the management of each individual zinc-smelting plant must decide for itself, according to local conditions, the feasibility of and the best methods for treating residues profitably. Results of the study are presented in more detail in Technical Paper 341.

Weather Forecasts in the Industries. (U. S. Department of Agriculture Clip Sheet No. 370, July 27, 1925.)—Split redwood products stored in the forest take a high rate of fire insurance during the dry season, but, as there is no fire loss during the rainy season, insurance is not carried. The rains have continued later than usual this season, and a lumber dealer reports, through the Eureka station of the Weather Bureau, that by closely watching the forecasts he has safely delayed insuring his products for more than three weeks, thus saving about $700 in premiums.

A company manufacturing cement formerly used 27,000,000 gallons of lake water a day in operating steam turbines, and was forced to shut down to avoid damage to machinery when the lake level occasionally fell below the water intake. On January 31, 1925, the weather map indicated conditions favorable for a sharp drop. The official in charge of the Weather Bureau station notified the company at noon that the lake level would fall sharply a foot or more about 4 P.M. The fall was so rapid that considerable damage would have resulted if the plant had not been prepared to shut down before the fall began.

THE FRANKLIN INSTITUTE.

MEMBERSHIP NOTES.

CHANGES OF ADDRESS.

MR. T. P. CHANDLER, Ithan Farm, Radnor, Penna.

DR. ELBERT C. LATHROP, in care of The Celotex Company, 645 North Michigan Avenue, Chicago, Ill.

MR. JESSE W. RENO, 1158 Fifth Avenue, New York City, N. Y.

NECROLOGY.

Mr. Lewis A. Riley, 902 Lafayette Building, 437 Chestnut Street, Philadelphia, Penna.

LIBRARY NOTES.

RECENT ADDITIONS.

ARMSBY, HENRY PRENTISS, and MOULTON, C. ROBERT.—The Animal as a Converter of Matter and Energy. 1925.

BRAGG, SIR WILLIAM HENRY.—The Crystalline State. 1925.

CRENSHAW, B. H., and KILLEBREW, C. D.—Analytic Geometry and Calculus. 1925.

Faraday Society.—Base Exchange in Soils: A General Discussion. 1924.

FRIEND, J. NEWTON (Editor).—Text-book of Inorganic Chemistry. Volume III, Part I, The Alkaline Earth Metals, by May Sybil Burr. 1925.

GARDNER, WILLIAM.—Chemical Synonyms and Trade Names. Companion volume to first edition. 1925.

Handbook of the Central High School of Philadelphia, 1924–1925. 1924.

Institute of Physics, London.—Physics in Industry. Volume 2. 1924.

Johns Hopkins University, School of Engineering.—Lectures on Engineering Practice. 1923–1924.

Klimsch's Jahrbuch. Volume 17. 1923.

NIELSEN, NIELS.—Traité Élémentaire des Nombres de Bernoulli. 1923.

Royal Society of London.—Philosophical Transactions. Series B, Volume 213. 1925.

TAYLOR, HUGH S. (Editor).—A Treatise on Physical Chemistry. Second printing—corrected. Two volumes. 1925.

Webster's New International Dictionary of the English Language. 1925.

BOOK REVIEWS.

BASE EXCHANGE IN SOILS. A General Discussion at the meeting of the Faraday Society, December 9, 1924. 67 pages, 8vo, limp cloth. From the Society.

For some years the Faraday Society has pursued the policy of broad discussion of physical and chemical questions at its meetings, publishing the papers and incidental remarks. Already a valuable and interesting collection has been

accumulated. Not long ago a symposium on the "Physical Chemistry of the Photographic Process" was reviewed in this JOURNAL.

Soil chemistry has been a subject of most extensive investigation for many years. The land is the source of all that is necessary for the food of man, and the means of improving the yield necessarily appeals to all civilized people. Yet the actual cultivators of the land have perhaps been the least active in studying the conditions of their labor. The backwardness of the farmer is proverbial. Two thousand years ago, Horace told the story—probably then a part of ancient folklore—of the country clown who waited until the stream should flow past, that he might cross (*Rusticus expectat, dum defluit amnis*).

The present report is a discussion of rather abstruse and recondite topics of soil chemistry and soil physics, for here as in many phases of applied science, nowadays, physics has intruded very markedly. Notwithstanding the extent of researches on soil chemistry and physics much yet remains to be done, and marked difference of opinion exists concerning some important points. In the United States some years ago a good deal of bitterness developed between agricultural chemists at large and a portion of the official group. The testing of soil for the pH value has been actively carried out of late years and many practical and theoretical results have been obtained. The bacteriology of soil is another field of investigation that has been fertile in results.

In view of the drift of population into the cities, the importance of increasing the fertility of land is a predominant problem. Those interested in soil science will find in the report of the discussion at the Faraday Society a large amount of valuable data, presented by experts who have employed fully the modern methods and principles of research. HENRY LEFFMANN.

BIBLIOGRAPHIE DE LA RELATIVITÉ, suivie d'un appendice sur les déterminants a plus de deux dimensions, le calcul des variations, les séries trigonométriques et l'azéotropisme. Par Maurice Lecat avec la collaboration de Mme. M. Lecat-Pierlot. xii–291–47 pages, 6½″ × 10″, paper. Brussels, Maurice Lamertin, 1924.

Since the first active investigation of the principle of relativity, contributions on the subject have been made at a constantly increasing rate until within the last few years a veritable avalanche of books and periodical articles have made their appearance, many of them the product of acknowledged leaders in scientific thought and mathematical analysis. It is obviously of prime importance to catalogue this valuable data for ready reference; this the author has done thoroughly.

The bibliography includes three principal lists. The first, under the names of authors alphabetically arranged, gives the titles of works and memoirs with reference to date, volume and page of periodical contributions. The second gives, also in alphabetical order, the names of periodicals with reference to the articles mentioned in the previous list. A third list is an abridged classification in chronological order of the contents of the first list.

In an appendix are given some shorter bibliographic collections, determinants of more than two dimensions and addenda to the author's bibliographies on The Calculus of Variations, Trigonometric Series, and Azeotropism which deals with the vapor pressures of liquid mixtures. These are presented in the

same form as the list on relativity under author's name. The annotations which accompany the various lists and the statistical information on the production of the literature on relativity are of great interest. The author makes no claim that the compilation is free of omissions and bespeaks an appreciation of any communication that may add to the usefulness of this comprehensive collection of 3375 titles.

The generous spirit shown by the author in laying aside enough of his own interest-absorbing investigations to assume the heavy burden of collecting and classifying bibliographic data adds to the welcome which the intrinsic usefulness of his work will enlist. LUCIEN E. PICOLET.

COMPANION TO THE FIRST EDITION OF CHEMICAL SYNONYMS AND TRADE NAMES. By William Gardner. 56 pages, 8vo. London, Crosby Lockwood and Son, 1925. Price, 7s. 6d.

Notice has already been given in this JOURNAL of the first edition of Gardner's "Chemical Synonyms." The present issue is a supplement intended to keep the work up to date. The material has been included in a second edition, but the supplement has been issued for the use of those who have the first. This is a somewhat novel method, but will be appreciated by many. The supplement contains about 2700 titles, and covers very useful and important lists of trade names and synonyms. The time seems now to be about at hand for the publication of a work on the loose-leaf principle, by which an encyclopedia of chemistry may be kept up to date without the expense of buying every year or so a new edition. HENRY LEFFMANN.

THE CRYSTALLINE STATE. By Sir William Henry Bragg, K.B.E., D.Sc., F.R.S. 31 pages, illustrated, 8vo, paper bound. Oxford University Press, American Branch, New York. Price, 70 cents.

This is the report of the Romanes Lecture, delivered May 20, 1925. The author stands most prominent in the research into crystal structure by means of Laue's method and its later expansions. The facts are set forth clearly and concisely. To the chemist the most interesting and important data are those in regard to the elucidation of the chain arrangements of the carbon atoms in organic substances. For many years teachers of chemistry have made use of graphic formulas to explain homology, isomerism, optical activity and other properties of organic bodies, but, as the author remarks, cautious teachers have always laid stress on the point that the arrangements were suggestive and not to be taken as actually existing. Sir William, however, in this lecture tells us that the chain and ring arrangements are definitely indicated by the X-ray methods. This will be good news to chemists, who by their very training are inclined to be Gradgrinds, wanting facts and nothing else. In the course of the lecture, a comparison was made between a bar of aluminum of ordinary nature, being a mixture of crystals, and one which by special treatment has been converted into a single crystal. The differences between the physical properties of the two are marked. This contrast is now pretty generally known, one of the most striking instances being the single copper crystals which have been produced in the United States. HENRY LEFFMANN.

PHYSICS IN INDUSTRY. Volume two, 48 pages, 8vo. The Oxford University Press, American Branch, New York, 1924. Price, $1.

This issue consists of reports of three lectures delivered before the Institute of Physics, as follows:

Applications of Physics to the Ceramic Industries, by J. W. Mellor.

The Physicist in the Textile Industries, by A. E. Oxley.

The Physicist in Metallurgy, by C. H. Desch.

Physics has always had a share in industrial affairs, but until lately it was principally in relation to the production and transmission of power and the handling of materials. Watt's development of the steam engine, which was the main influence in bringing about the industrial revolution, now the dominant feature of modern life, was a purely physical question. The composition of water had been studied with much vigor by British and Continental chemists, but Watt was not interested in the chemistry of steam but in its properties as a source of power. It is well known that Watt is among the comparatively few great inventors of earlier days who acquired a fortune by his work, but Sir Charles A. Parsons, who contributes an introduction to the report, says truly that this result was mainly due to the partnership of a sympathetic business man, Matthew Boulton. Present-day conditions have not dealt as parsimoniously with inventors as formerly, for considerable fortunes have been acquired by those who have entered into studies in the applications of science, though it is still true that the great fortunes have accrued to those who have special business ability.

The three lectures in the report, together with the introduction by Parsons, present a very serviceable picture of the manner in which modern physical data find application in solving problems in the several industries that are considered. This intrusion of physics into fields that have heretofore been essentially chemical does not mean, however, that the chemist can be laid off. Lots of problems still remain for the services of those who deal with what used to be called the "forces acting at invisible distances," especially chemical affinity.

HENRY LEFFMANN.

TRAITÉ ÉLÉMENTAIRE DES NOMBRES DE BERNOULLI. Par Niels Nielsen, Professeur a l'Université de Copenhagen, Membre de l'Académie Royale des Sciences de Danemark. x–398 pages, 10″ × 6½″, paper. Paris, Gauthier-Villars et Cie., 1923. Price, 50 francs.

The use of Bernoulli numbers in the expansion of functions is usually dwelt upon only quite briefly in present-day text-books on the calculus and with little if any reference to their mode of derivation. One must search in such special treatises as those of Herschel and Boole on the calculus of finite differences or in the old works on the calculus like those of De Morgan and Lardner for an account of the derivation of these numbers or better in the works of the great masters, Bernoulli and Euler, and the fragmentary contributions of later writers of note in periodical literature.

It was the author's original intention in the development of this comprehensive treatise to search mathematical literature as carefully as possible in order to settle questions of priority, the war, however, interfered with the fullest attainment of that aim. This fact notwithstanding, the numerous foot-

notes of references to original sources bear testimony to painstaking research in his critical analysis of the contributions of numerous investigators. It is especially noted from the historic viewpoint how the widespread adoption of transcendental methods in dealing with the theory of Bernoulli numbers deterred rather than aided its development. James Bernoulli (1654–1705) in his posthumous work *Ars Conjectandi* introduced by perfectly elementary methods an infinite series of rational numbers which later became celebrated under the name *Numbers* of *Bernoulli* and the Swiss mathematician calculated the first five of these numbers. Twenty years later the same series was rediscovered by Euler and such was the influence of this great leader that subsequent investigators adhered to his transcendental methods quite unmindful of the simpler and more direct method of Bernoulli. The elementary theory which the author develops, it is pointed out, is much more fundamental than the symbolic one in that it yields direct results for all the numbers of Bernoulli series.

The meticulous detail in which the subject is developed with its critical and historic references cannot fail to prove of rare interest to the mathematician who is accustomed to deal with general methods. On the other hand, those who deal with specific applications will find it difficult to isolate from this unusually rich collection of analytical deduction and data the expressions adapted for their particular needs. The work is of especial value in supplying a directive and authoritative standard of reference. LUCIEN E. PICOLET.

THE TESTING OF HIGH-SPEED INTERNAL COMBUSTION ENGINES. By Arthur W. Judge. xvi–392 pages, 6″ × 9″, cloth. New York, D. Van Nostrand Company, 1925. Price, $7.50.

There are reports without end of tests of power-producing machinery scattered in the files of periodical technical literature which include every type of plant in current practice. Satisfactory accounts of the practice of conducting such tests and descriptions of suitable appliances for the purpose are also to be found in several text-books on experimental engineering, but there appears to be no work available antedating the present volume, which deals specifically with the testing of the high-speed gas engine.

The work, so the author says, "is written with a definite object for the average type of testing individual, to give a more or less general account of the subject." This rather casual phrase scarcely does the book justice. As books of this sort go, that is, for a practical treatise which is not intended to be exhaustive, the subject is very fully treated and in great detail.

The first chapter deals with the basic principles underlying the testing of engines, and contains much valuable data in usable form on the theoretical side of the subject. The work of Ricardo is referred to at some length and includes an illustrated description of his variable compression test-engine. The next chapter is on test procedure. Here the different arrangements for conducting tests of various kinds and methods of recording data are discussed. These two important chapters cover seventy pages. The subsequent chapters are devoted to a description of the component measurement apparatus of the test installation. The several forms of the various devices of modern design employed are discussed at length and their advantages and limitations pointed out.

Among the especially modern apparatus may be mentioned several forms

of fuel flowmeters which indicate the rate of fuel consumption. Flowmeters for indicating the rate of air-consumption are also described at length. In both cases volumetric methods of measurement are also considered and for fuel, weighing methods as well. The chapter on brakes leaves little to be desired in point of fulness and choice of subject-matter. The Coales self-adjusting brake and the Griffin brake among the rubbing-surface brakes are modern designs of this type. Fluid-friction brakes, however, are preferred, Several forms are described, including the Alden and the Froude. Fan-brakes, electromagnetic brakes and electric absorption dynamometers are also considered. The section on transmission dynamometers includes two forms of torsion meters, one of them recording. The chapter closes with a section on speed-measuring instruments.

High pressure and temperature are features peculiar to the gas engine, consequently the chapters on pressure and temperature measurement are appropriately accorded 108 pages. Here a very full account is given of single-pressure indicators and cyclical-pressure indicators, among them the micro-indicators in which inertia effects are overcome by reducing the size of the diagram traced to minute dimensions, to be afterwards enlarged photographically, and the highly developed optical indicators of which the Carpentier instrument of perhaps thirty years ago applied to the early motorcycle engine was a forerunner. The various forms of thermocouples are of especial interest and are fully described. There are chapters on automobile and aircraft testing of satisfactory fulness. The last chapter is on the analysis of high-frequency movements with especial reference to the motion of cam-operated, spring-controlled valves. Here cinema photography and direct vision optical devices are employed.

The above summary is by no means complete, it is merely representative. If there are any omissions they are few and probably unimportant. The test engineer will find therein the material both to refresh his memory on principle and sound practice and a highly informative account of *fin de siecle* equipment. The typographical work is beyond reproach. LUCIEN E. PICOLET.

A TEXT-BOOK OF INORGANIC CHEMISTRY. Vol. 3, part 1. The Alkaline Earth Metals. By May Sybil Burr, D.Sc. xxvi, 346 pages, 8vo. Philadelphia, J. B. Lippincott Company, 1925. Price, $9.50.

This series, published under the editorship of Dr. J. Newton Friend, is now well known to chemists, a considerable number of the volumes having already appeared and some have been reprinted. As the individual volumes are in the hands of special collaborators the publication has not been entirely consecutive. The volume now under review is the work of Mrs. Burr, and is a very creditable production, all, indeed, that the teacher of chemistry, or the research chemist would need for information on the general chemistry of the elements included. In accordance with the now-general practice in works on inorganic chemistry, the periodic classification is the basis of the arrangement. This brings radium into the book, and an excellent summary is given of its chemistry and of its remarkable transformations. The speculations of geophysicists as to the age of the earth based on the rate of decay of radium are given, but this is space wasted. The authoress quotes from Joly the remark that such inferences are unsafe inasmuch as the calculation is based upon the assumption—which may

not be correct—that the rate of radio-active change has been constant throughout the entire period. In view of the earnestness and bitterness with which certain portions of the community are now challenging the inferences of scientists as to the course of events and the lapse of time in the remote past, it is well for writers of text-books of this type to confine themselves to ascertained facts of the science, or at least to limit speculation to the nature of the phenomena observed. It is to be noted that in the book two tables of length of geologic periods are given and that they are widely different. The values are both much higher than those that have been calculated by assumption of rate of sedimentation or denudation. In such speculations chemists stray from their legitimate functions, and may be said to enter upon the method which John Phoenix suggested for determining the distance of the asteroids—guess half the distance and multiply by two.

The method of presenting the data is excellent. An enormous amount of information is included within the compass of the volume; the references to the literature are most extensive and in detail, year and volume being always given if the two data are available. A minor criticism must be made of the use of "*ibid.*" It is preferable to repeat the whole reference. The free use of tabular matter enables the introduction of many data with economy of space. The style is clear and concise and the book shows that the authoress is thoroughly familiar with the subject and skilful in condensing the immense store of information scattered through the literature. Two excellent indexes—names and subjects—are included.

The publisher's methods are not wholly commendable. While the mechanical execution of the book is entirely satisfactory—the sheets were printed in England—the system of paging a limited portion of the introductory matter in Roman numerals is unnecessary and awkward. More objectionable is the division of separate volumes into parts instead of numbering each portion as a volume in consecutive order as the final arrangement will be in the completed work. This division of volumes into parts was used in the original editions of Allen's "Commercial Organic Analysis," but was wisely discontinued when the American publisher took over the work. It is to be hoped that the series will soon be completed and chemists will have a comprehensive and trustworthy text-book of inorganic chemistry. HENRY LEFFMANN.

A TREATISE ON PHYSICAL CHEMISTRY. Edited by Hugh S. Taylor, D.Sc. In two volumes, including a total of 1359 pages of descriptive text, 20 pages of preliminary matter, contents and preface and 23 pages of indexes given in each volume. Illustrated. New York, D. Van Nostrand Company, 1925. Price, $12.

This work is a coöperative production of sixteen specialists with the direct assistance of the editor, who has contributed articles to both volumes. The work is entitled "second printing—corrected," which presumably means a second edition. When one considers the short chapters on "chemical physics" that formed part of the text-books on inorganic chemistry a couple of generations ago, the growth of that phase of chemistry is almost appalling. The work under review contains more descriptive matter than would have been found in a complete text-book of inorganic chemistry of fifty years ago. Specialism has

invaded the field, as is shown by the numerous collaborators that have shared in the work. The editor speaks of this in his preface: "The adequate treatment of the subject of modern physical chemistry is a difficult task for any one person." It might, indeed, be considered impossible. More impressive are the editor's words concerning the present status of physical chemistry with reference to general chemistry and general physics and the outlook for the future: "It will be generally recognized that a new era in physical chemistry is upon us. The science of a decade ago is utterly inadequate to present-day demands. The atom is no longer a philosophic concept, but a concrete reality; no longer, however, atomic or indivisible. Energy is considered less and less as a continuum, more and more in units and quanta * * *. The classical tradition of physical chemistry was the study of the individual from the behavior of the crowd. Are there not signs that the behavior of the crowd can be deduced from the study of the individual? It is with such thoughts in mind that the plan of the book took shape."

It is not an elementary work, but intended for the advanced student and the research worker in industry who requires information on the theoretical treatment of his practical investigations. Notwithstanding this basic principle, the first volume has value to the student who has proceeded moderately in his studies of the subject. The first chapter is, indeed, an introduction to the standard concepts of chemical actions as accepted at present. It is gratifying to note the sentence, "The inception of the modern era in chemical science may be attributed to the proposal of the atomic theory of chemical action by John Dalton in his first volume of 'The New System of Chemical Philosophy, 1808.'" Doctor Taylor does not subscribe to the view that chemistry is a French science entirely. Boyle is also given credit. No chemist would wish to deny the great part that Lavoisier's researches had in developing chemistry into an exact science, but the claim that he alone is originator of this development is a mistake. All human progress is a slow evolution. Many of the steps are so slight or seemingly so disconnected that progress on ordinary scrutiny appears by jumps, but close observation shows the contrary. It is as a rule impossible to establish who was the beginner of a given development. The Wright brothers are receiving credit for the real progress in aviation, yet it is cruel and unjust to ignore Langley's patient and scientific labors, prevented by hostile conditions from reaching complete control of the air. Indeed, as Schley telegraphed after the battle of Santiago, "there is glory enough for all." There is no justice in any nation claiming primacy in any phase of human progress.

However, the book in hand is not an essay on philosophy or ethics, but an elaborate treatise on a very difficult and highly specialized phase of physical science. It is another evidence of the manner in which physics is invading chemistry. One of the most interesting chapters in the book is that on the use of the X-ray for determining the arrangement of atoms. Recently, Sir William Bragg delivered a lecture on this topic and pointed out that the method had been applied to distinguish the validity of the common theories of open and closed chains in organic bodies and has confirmed those views.

It remains to be said that the text of the work is clear and exact, the illustrations and tables numerous, the mechanical execution all that can be desired. The additions that have been made to standard chemical literature, both pure and

applied, in Great Britain and the United States of recent years have really rendered students independent of Continental text-books. The development of teaching methods makes it no longer necessary to go abroad to learn, but it is to be hoped that this new declaration of independence will not lead to neglect of French and German literature, in which so much of the record of progress is to be found.

HENRY LEFFMANN.

L'INDUSTRIE DES PRODUITS CHIMIQUES ET SES TRAVAILLEURS. By A. Matagrin. xviii–486 pages, illustrated, paper bound, 12mo. Paris, Gaston Doin, 1925. Price, 12 francs.

This is a volume of a series entitled "Bibliothèque social des Métiers," published under the direction of Georges Renard. In France, as in other countries that were arrayed against Germany, much effort has been made to develop industrial chemistry in the theoretical as well as practical phases, obviously induced by the manner in which the German industrial establishments demonstrated their value in war. The series is not intended to supplant the books in technology proper, but to discuss briefly the history of the given industry, its organization and administration, questions of employment, of relations between employers and employed, wage problems, hours of labor, supervision of shops, insurance, amelioration of the conditions of laborers, apprenticeships, in other words, all the problems of labor now so complex and serious in all civilized nations, especially in those which have developed a large industrial life.

The volume in hand relates to the problems in industrial chemistry. Much information is given of interest to those who would like to see what France is doing in these lines. One turns naturally to the chapter in which the nitrogen-fixation problem is presented. The chapter is too long for even partial abstract here, but it is noted that in November, 1919, Loucheur, who was the administrator of the territories taken over from the Germans, negotiated with the *BASF* an agreement by which the Haber-Bosch patents were made available for French use. It was not, however, until 1923 that a government factory for the operation of the patent was established. The delay is ascribed to the opposition of the conservative (right) branch of the legislature. The plant, which is at Toulouse, has a capacity of 36,000 tons of ammonium sulphate per annum. It is stated that in 1914, Germany produced 500,000 tons of ammonium sulphate, while France had to rely on the ammonia extracted from gas liquor and the limited supply of Chile nitrate that could escape the German submarines. It is now well known that Claude has developed important and useful features of the nitrogen-fixation methods. The book contains a large amount of information on the problems of industry as now presented in France.

M. Matagrin has made himself familiar with the details of labor problems in America, Great Britain and Germany, including not only the purely economic issues between capital and labor, but the liability of workmen in certain industries to serious disease. In discussing one phase of the problem of the general worker, as contrasted with the capitalist and the technician, we encounter the word "taylorisation," obviously referring to the efficiency systems of our American engineer, who shares honors with Captain Boycott of constituting a word in a language which has not been very absorptive towards the languages

of the nations around it, but business is business nowadays and economic influences override all sentiment. The cosmopolitan character of the book gives it great value and interest. HENRY LEFFMANN.

THE ANIMAL AS A CONVERTER OF MATTER AND ENERGY. By (the late) Henry Prentiss Armsby and C. Robert Moulton. American Chemical Society Monograph Series. 236 pages, 8vo. New York, The Chemical Catalog Company, 1925. Price, $3.

The list of monographs prepared under the auspices of the American Chemical Society has grown to an imposing length, and includes a very wide range of subjects. A list of those in preparation indicates that the comprehensiveness of the plan will suffer no restriction. Director Armsby did not live to see the completion of this essay and it was finished by the labors of Professor Moulton. The title has a slightly cryptic form, but essentially the work is devoted to what the sub-title indicates, "The rôle of live-stock in food production." That man cannot live by bread alone has long been an axiom among the great majority of persons, although an appreciable minority has loudly proclaimed the virtue of vegetarianism. There is indeed some indication that in the Hebrew story of primitive man, only vegetable diet was permitted, for stress seems to be laid on the "green herb for meat" as man's food. We know unfortunately so little of the early history of man that it is unsafe to present definite views, but the remains of the cave-dwellers and the collections of refuse in other places show that man early indulged in animal food. Perhaps even in the earliest periods of pastoral life, eggs and milk were eaten in association with plants and these will furnish the calories, proteins, carbohydrates, fats and vitamins necessary according to modern views to healthful growth.

However, the work in hand is not concerned with origins. It is an up-to-date presentation of the part taken by the food-animal in supplying nutrition to human beings. Man in his more civilized state eats mainly herbivora, as far as regards the mammalia, but with birds, reptiles and fishes, his taste is not so exclusive. Our common food-animals are, as the authors point out, practically competitors of man for the direct products of the earth, although our stock can digest parts of plants, such as the stems of grasses, while man can utilize only part of the seed. It has, indeed, been claimed as a result of some experiments made during the stress of war in Germany that a limited amount of cellulose mixed with flour can be assimilated. The information is academic. Sawdust pudding is not likely to be acceptable. The comprehensiveness of animal foods is set forth. Animal proteins have, as a rule, a higher biologic value than vegetable proteins, being especially necessary to the growing child. Animal fats in themselves are not of greater value than vegetable fats, but the recent discoveries in regard to the presence of vitamins in the former determine a choice. On the other hand, carbohydrates, except as regards the lactose of milk, are derived from vegetable sources. Milk is lacking in iron, as Bunge long ago pointed out. Flesh supplies this and also phosphorus. Calcium is lacking in many foods but is present in milk in notable amount.

The work includes discussions of the raw materials (feeding stuffs); the finished products, meat, milk and eggs; the processes of digestion and absorp-

tion and the phenomena of metabolism. A second section is devoted to the study of the quantitative relations in feeding, and the efficiency of conversion. Overhead feed cost, net efficiency and gross efficiency are the final topics. The text is largely supplemented by tables, and the work, therefore, constitutes a highly useful contribution to a most important phase of the relation of land to the support of the human being. HENRY LEFFMANN.

HANDBOOK OF THE CENTRAL HIGH SCHOOL OF PHILADELPHIA. Second edition. 243 pages, 49 illustrations. Philadelphia, The Mary Gaston Barnwell Foundation, 1924.

Much material has been added to this handbook since the publication of the previous edition in 1922 (see review in JOUR. FRANK. INST., 1923, 195, 415). The text contains much information of value to all who are interested in higher education, *e.g.*, the description of the plans for faculty advisors, college and vocational guidance, and industrial placement. Among the new sections may be mentioned "A Moral Code for Young Americans," "What to Eat and Why," "Health and Hygiene," and "Good Citizenship." Among the illustrations are group pictures of the faculty by departments, and portraits of all the presidents of the school. The various activities of the Barnwell Foundation for the benefit of the students and graduates of the school now include a library, addresses, publication of a leaflet and a bulletin, and an Honor Roll of students with appropriate insignia. The handbook concludes with a biographical sketch of James Gaston Barnwell, a Master of Arts of the Central High School, who bequeathed approximately one-third of a million dollars for the endowment of the Mary Gaston Barnwell Foundation in memory of his mother, and to encourage and reward the practice of the highest principles of honor and moral courage, regardless of immediate or apparent results, by the students and graduates of the school. JOSEPH S. HEPBURN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS. Report No. 210, Inertia Factors of Ellipsoids for Use in Airship Design. By L. B. Tuckerman. 7 pages, quarto. Washington, Government Printing Office, 1925. Price, five cents.

This report is based on a study made by the writer as a member of the Special Committee on Design of Army Semi-rigid Airship Rs-1 appointed by the National Advisory Committee for Aeronautics.

The increasing interest in airships has made the problem of the potential flow of a fluid about an ellipsoid of considerable practical importance. In 1833 George Green, in discussing the effect of the surrounding medium upon the period of a pendulum, derived three elliptic integrals, in terms of which practically all the characteristics of this type of motion can be expressed. The theory of this type of motion is very fully given by Horace Lamb in his "Hydrodynamics," and applications to the theory of airships by many other writers. Tables of inertia coefficients derived from these integrals are available for the most important special cases. These tables are adequate for most purposes, but occasionally it is desirable to know the values of these integrals in other cases where tabulated values are not available. For this reason it seemed worth while to assemble a collection of formulæ which would enable

them to be computed directly from standard tables of elliptic integrals, circular and hyperbolic functions, and logarithms without the need of intermediate transformations. Some of the formulæ for special cases (elliptic cylinder, prolate spheroid, oblate spheroid, etc.) have been published before, but the general forms and some special cases have not been found in previous publications.

Report No. 216, The Reduction of Airplane Flight Test Data to Standard Atmosphere Conditions. By Walter S. Diehl and E. P. Lesley. 18 pages, illustrations, quarto. Washington, Government Printing Office, 1925. Price, ten cents.

The present report was prepared for the committee in order to supply the need of practical methods of reducing observed performance to standard conditions with a minimum of labor. The first part gives a very simple approximate method of reducing performance in climb, and is particularly adapted to work not requiring extreme accuracy. The second part gives a somewhat more elaborate and more accurate method which is well suited to general flight-test reduction. The third part gives the conventional method of calibrating airspeed indicators and reducing the indicated speeds to true airspeeds. An appendix contains working tables and charts for the standard atmosphere.

PUBLICATIONS RECEIVED.

Handbuch der Radiologie. VI. Die Theorien der Radiologie, by Laue, Zeeman and others. xii–806 pages, illustrations, 8vo. Leipzig, Akademische Verlagsgesellschaft, 1924. Price, 40 marks.

Towles' Portrait Lightings, by Will H. Towles. 103 pages, illustrations, quarto. Philadelphia, Frank V. Chambers, 1925.

Beverage Blue Book, 1925. 336 pages, 8vo. Chicago, H. S. Rich and Company, 1925.

Bau und Betrieb moderner Konverterstahlwerke und Kleinbessemereien, von Hubert Hermanns. 251 pages, illustrations, 8vo. Halle, Wilhelm Knapp, 1925.

U. S. Department of Agriculture: Weather Bureau. Daily River Stages at River Gage Stations on the Principal Rivers of the United States. Volume xxii, 1924. 183 pages, quarto. Washington, Government Printing Office, 1925.

Lighting, Fundamentals of the Application of Electric Energy, by Michael E. Zelentsoff. xvi–432 pages, illustrations, tables, 8vo. Leningrad, Couboutch, 1925. Price, $1.65.

U. S. Department of Commerce: Scientific Paper of the Bureau of Standards, No. 503, A Flow Calorimeter for Specific Heats of Gases. 35 pages, illustrations, plates, quarto. Washington, Bureau of Standards, 1925.

Faraday Society. Report of the Council and Statement of Accounts to be Presented at the Annual Meeting, July 6, 1925. 11 pages, 8vo. London Society.

U. S. Department of Agriculture: Inventory No. 74, Seeds and Plants Imported by the Office of Foreign Seed and Plant Introduction during January 1 to March 31, 1923. 42 pages, plates, 8vo. Washington, Government Printing Office, 1925.

National Research Council: Bulletin, March, 1925, Bibliography of Bibliographies on Chemistry and Chemical Technology, 1900–1924. 308 pages, 8vo. Washington, National Research Council, 1925.

National Advisory Committee for Aeronautics: Technical Notes, No. 211, Aircraft Engine Design, by E. E. Wilson. 20 pages, plates. No. 221, Model Tests on the Economy and Effectiveness of Helicopter Propellers, by Max M. Munk. 26 pages, plates. No. 222, Air Flow Investigation for Location of Angle of Attack Head on a JN4h Airplane, by R. G. Freeman. 13 pages, plates, quarto. Washington, Committee, 1924.

Kolloidchemie ein Lehrbuch, von Richard Zsigmondy. Edition 5, part 1. xii–246 pages, illustrations, plates, 8vo. Leipzig, Otto Spamer, 1925. Price, 11 marks.

Bell Telephone Laboratories. Reprints: The Distribution of Initial Velocities among Thermionic Electrons, by L. H. Germer. 17 pages, illustrations. Production of Single Sideband for Trans-Atlantic Radio Telephony, by R. A. Heising. 22 pages, illustrations, plates, 8vo. New York, Company, 1925.

Butesin Picrate.—The preparation and properties of this compound are described by FLOYD K. THAYER (*Am. Jour. Pharmacy,* 1925, **97**, 39–42). Butesin is the normal butyl ester of para-aminobenzoic acid. It combines with picric acid, in the ratio of one molecule of the acid to two molecules of the ester. Both the ester and the acid may be dissolved in benzene, and the two solutions mixed; or the ester may be dissolved in water containing hydrochloric acid, then added to an aqueous solution of picric acid; or an alcoholic solution of butesin may be mixed with an aqueous solution of picric acid. Butesin picrate deposits as a flocculent mass; 1 part dissolves in 100 parts of cottonseed oil, or in 2000 parts of water; it is readily soluble in alcohol and ether. It possesses both anæsthetic and antiseptic properties, and is applied in an ointment, as a solution in oil, or as a dusting powder. It is of value in the treatment of burns.

J. S. H.

Cloth from String Beans. (*Popular Science Monthly,* September, 1925, p. 71.)—A process for making coarse cloth from the fibres of string beans was perfected recently for commercial use in Austria. The bean shells are treated like hemp, and the fibre that results can be spun, making a hard but strong yarn.

This new material is expected to offer competition to hempen products. It is adaptable for making materials for which cotton has been used heretofore, and it can be used in making carpets, curtains, upholstery, and saddlery after it has been bleached properly and printed.

Alcohol from Prickly Pear for Motor Fuel. (*Popular Mechanics,* September, 1925, p. 411.)—A process for extracting alcohol from the prickly pear, of which there are thousands of acres in Australia and other countries, promises important use of this hitherto worthless plant. According to the discoverer of the method, the alcohol is suitable for motor fuel.

R.

CURRENT TOPICS.

The Synthesis of Common Alcohol.—The monatomic alcohols, of which common alcohol is the most familiar example, from which the group has derived its name, bear such simple relations to the paraffins and olefins that synthetic transformation of the latter into the former has for a long while been attempted. The procedures are all the more attractive as the hydrocarbons are abundant, not only in natural products, such as petroleum and natural gas, but are easily obtained in quantity by the distillation of coal and wood. Berthelot, many years ago (*Chim. Organ.*, etc., 1860, Vol. 1, 121) succeeded in converting ethylene into alcohol by agitating it with sulphuric acid, producing sulphovinic acid, followed by saponification. The procedure had no technical value on account of cost.

Similar methods of synthesis can be applied to the other hydrocarbons. For several years past an excellent quality of iso-propyl alcohol has been in the market, made by one of the great oil corporations from the propylene existing in the raw materials. Isomerisms begin, of course, to appear in all the series when the carbon atoms are above two, and the product of the propylene synthesis is the secondary form that yields a ketone not an aldehyde on limited oxidation. Lately, as is now widely known, German and French factories have introduced a synthetic methanol (methyl alcohol) at a price which seriously threatens the American industry in which distillation of wood is used.

Cheap methods of producing common alcohol (ethanol) have become very important owing to the introduction of the combustion motor. It would be a satisfactory substitute for gasoline in several ways: The more agreeable odor, lessened fire-risk, certainty of continual supply and probably better combustion, therefore, producing less carbon monoxide, which is a serious sanitary danger with the ordinary motor fuel. Some great nations, Great Britain, France and Italy, lack supplies of oil and gas on their own territories, and are alarmed, in view of the greatly increased use of combustion motors in war, at the possible curtailment of their resources by blockade. Many attempts have been made to cheapen the process of fermentation which is still the main source of alcohol. Refuse and by-products of many industries have been tried. Any material containing certain carbohydrates, which are abundant in all parts of the world, may be converted into alcohol by simple methods, but in many cases the labor and transportation costs prevent commercial success. In all the great nations the manufacture and sale of ethanol is subject to strict taxation and other control, and the procedures must be carried on under personal supervision. All farms have more or less refuse

available, but fermentation and distillation must either be conducted under the eye of a government agent or the small quantities of material transported to some point where large-scale production can be carried out. Both conditions impose expenses that are usually prohibitory.

It is, therefore, with considerable interest that one reads a paper appearing in *Chimie et Industrie* (1925, 13, 718) giving a comprehensive account of the operation of a plant by a mining company at Bethune, France, for the manufacture of ethanol from ethylene. The paper is contributed by F. Vallette, Assistant Director of the works. Notice is made of a process by hydration of acetylene by which aldehyde is formed, which can then be hydrogenated to ethanol. This method fails, at present, commercially on account of the cost of calcium carbide, which is the source of the acetylene. The process which is adopted at Bethune, uses the ethylene existing in the gas obtained from by-product coke ovens. At this plant also, Claude's method of ammonia synthesis is operated. The coke-oven gas is subjected to cold and pressure in consecutive degrees, by which several of the admixed gases are liquefied, among them the ethylene. Benzene, methane, carbon monoxide and many other accessories are eliminated. Incidentally, it is stated that the gas obtained by cracking petroleum may contain 20 per cent. of ethylene, but this fact has no application at the French plant. A notable profit results from the obtaining of considerable amounts of benzene by the cooling. Data given are that a plant carbonizing 100 metric tons (closely equal to 100 long tons) will yield about 1700 pounds of benzene, and about a ton of ethanol, presumably nearly absolute, but this datum is not given. The costs and value of the products are stated, but these have no application to American conditions. The procedure is, briefly, the concentration of the ethylene from the coke-oven gas, to about 25 per cent. of the volume and its conversion into ethyl hydrogen sulphate (sulphovinic acid), which is then saponified in a special dephlegmator tower by the aid of ammonia, thus producing a commercially valuable ammonium sulphate. One cubic metre (35.3 cubic feet) of ethylene requires about 6.75 pounds of sulphuric acid and yields about 4.5 pounds of alcohol. As noted above, the strength of the alcohol is not given, but it is probably a high percentage product.

Vallette, in conclusion, states that the procedures are not tentative, but are carried out successfully. The basic industry of the plant enables the alcohol production to be interlocked with other operations so as to secure economy. France is especially interested in the production of efficient motor fuel within its own territory, and the issue of *Chimie et Industrie* from which the above data are taken contains the conclusion of a long article by A. Travers on the critical conditions in France regarding the supply of such fuel. Many possible sources are discussed, including fermentation, cracking of hydrocarbon and fatty oils, low-temperature distillation of coal and synthetic methods. The production of alcohol by fermentation decreased considerably in

consequence of German occupation and subsequent destruction of the factories in northern France.

After all, the existing condition is emphatically that oil instead of having the soothing, emollient effect formerly characteristic of it, is now the most serious disturber of the world's peace, although rubber seems to promise to add to the trouble. H. L.

Effect of Humidity on Hardness of Varnish. (*Technical News Bulletin*, Bureau of Standards, June, 1925, No. 98.)—During the past month hardness measurements have been made on samples of varnish received for test in the bureau's laboratory. For this work the swinging-beam method, as described by Walker and Steele in Circular 229 of the Paint Manufacturers' Association of the United States, has been employed.

The marked effect of humidity on these measurements was brought out on a very humid day in the laboratory. For instance, a spar varnish with a drying period of two days showed a hardness factor of 0.333, the relative humidity being 50 per cent. At four days, with a humidity of 60 per cent., the hardness factor was 0.387. At six days, with a humidity of 80 per cent., the hardness factor was only 0.240, while at seven days, with a humidity of 50 per cent., the hardness factor was 0.447.

The marked decrease in hardness factor on the sixth day, when the humidity was 80 per cent., is noteworthy.

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